MIGRATION OF ADULT STEELHEAD PAST DAMS AND THROUGH RESERVOIRS IN THE LOWER SNAKE RIVER AND INTO THE TRIBUTARIES, 1991-1995

Part II of final report for

MIGRATION OF ADULT CHINOOK SALMON AND STEELHEAD PAST DAMS AND THROUGH RESERVOIRS IN THE LOWER SNAKE RIVER AND INTO TRIBUTARIES

by

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U.S. Army Corps of Engineers
Walla Walla District

and

Bonneville Power Administration
Portland, Oregon

2003

Preface

A study of adult salmon and steelhead migrations past dams, through reservoirs, and into tributaries of the Snake River began in 1990 with planning, purchase and installation of radio telemetry equipment. Adult spring and summer chinook salmon were outfitted with transmitters in 1991-93, and adult steelhead in 1991-94. Progress reports have been issued periodically (Bjornn et al. 1992; 1994; 1995) and final reports as listed below. Part I of the final report includes a general introduction, methods that apply to all segments of the work and information on passage of chinook salmon. Other parts of the final report include an introduction and methods section specific to the topic covered.

Part I - Passage of chinook salmon through the lower Snake River and distribution into tributaries 1991-1993.

Part II - Passage of adult steelhead through the lower Snake River and distribution into tributaries 1991-1995.

Part III - Entrances used and passage through fishways for salmon and steelhead.

Part IV - Turbine priority and its effects on passage of steelhead at Snake River dams.

Part V - Movements of steelhead in fishways in relation to transition pools.

Part VI - Evaluation of fishway fences and spill for adult salmon and steelhead passage at lower Snake River dams.

Part VII - Effects of zero versus normal flow at night on passage of steelhead in summer and fall.

Acknowledgments

Many people assisted in this project and the successful completion was made possible by Teri Barila, the Corps of Engineers project officer. Michelle Feeley, Matthew Keefer, Brian Hastings, and Charles Nance also assisted in data collection and analysis.

Table of Contents

Preface ... ii
Abstract ... v
Introduction ... 1
Methods ... 1
Trapping and Tagging ... 1
Steelhead in 1991 ... 2
Steelhead in 1992 ... 2
Steelhead in 1993 ... 2
Steelhead in 1994 ... 2
Transmitter Retention ... 5
Passage Success and Migration Rates ... 5
Timing of Steelhead Migration and Distribution into Tributaries ... 6
Passage Success ... 6
1991 ... 9
1992 ... 10
1993 ... 10
1994 ... 11
Time to Pass Dams ... 11
1991 ... 11
1992 ... 12
1993 ... 12
1994 ... 12
Passage Rates of Hatchery Versus Wild Steelhead ... 15
Migration Rates Through Reservoirs ... 15
1991 ... 15
1992 ... 18
1993 ... 27
1994 ... 27
Migration Rates of Hatchery and Wild Steelhead ... 28
Time to migrate from Ice Harbor to Lower Granite Dams ... 28
Migration Rates Through Free-Flowing Rivers ... 29
1991 ... 29
1992 ... 32
1993 ... 33
1994 ... 35
Migration Rates of Hatchery and Wild Steelhead ... 36
Fallback of Steelhead at the Dams ... 36
1991 ... 37
1992 ... 38
1993 ... 39
1994 ... 40
Timing of Migration Past Dams and into Tributaries ... 41
Seasonal Timing of Migration at Dams ... 41
Seasonal Timing of Migration at Tributary Sites ... 41
Seasonal Timing of Hatchery Versus Wild Steelhead ... 41
Seasonal Timing of Migration of Major Tributary Stocks at Dams ... 41
Diel Time of Migration ... 62
Timing of Migration Related to Wintering Over ... 62
Distribution of Steelhead into Tributaries ... 77

Recaptures of Tagged Steelhead 82
1991 82
1992 82
1993 82
1994 85
Survival of Steelhead with Transmitters 85
Discussion 87
References 93

Abstract

Migrations of four fish-year runs (1991-1995) of adult steelhead *Oncorhynchus mykiss* were studied as they passed through the lower Snake River and into tributaries. We trapped and outfitted 2,812 steelhead with radio transmitters and released them near Ice Harbor Dam (1991, 1992, and 1994) and in the south fishway at John Day Dam (1993). Proportions of steelhead that passed and those that fell back over each dam were assessed, and migration rates through reservoirs, past dams and through free-flowing river reaches were calculated. Timing of steelhead migrations past dams and into tributaries was monitored at fixed-site radio receivers. Distributions of steelhead into tributaries were determined based on last records at fixed-site radio receivers, mobile tracks, and records of recaptures by anglers or at hatcheries and weirs.

During the four fish-years of study, counts of upriver steelhead at Bonneville Dam ranged from 160,767 in 1994 to 313,873 in 1992. The percentage of the steelhead counted at Bonneville Dam that entered the Snake River and were counted at Ice Harbor Dam ranged from 30.8% in 1994-95 (49,450 steelhead) to 53.0% in 1992-93 (166,654 steelhead).

Smaller proportions (21 to 45%) of steelhead released with transmitters in summer migrated past Lower Granite Dam than steelhead released in fall (44 to 83%).

Fallback rates were consistently low (2 to 6%) in all years at all dams, with the exception of Ice Harbor Dam in 1991 and 1992, when a relatively high percentage of the steelhead, particularly steelhead released in summer, appeared to have fallen back over the dam. Technical problems at Ice Harbor in those years may have led to inflated fallback estimates.

Median times for steelhead with transmitters to pass the four lower Snake River dams ranged from 0.3 to 2.0 d. Passage times were more than one day at Lower Granite and Ice Harbor dams where traps were operated in the fishway, and less than one day at Lower Monumental and Little Goose dams. In 1993 and 1994, when trapping in the Ice Harbor fishway was reduced, median passage times were 0.7 and 0.5 d, not significantly different from times at Lower Monumental or Little Goose dams.

Migration rates of steelhead with transmitters through reservoirs were typically between 15 and 30 km/d. There was no consistent difference in reservoir migration rates for steelhead released in summer versus fall or for steelhead migrating in fall versus spring. Migration rates of steelhead through unimpounded rivers tended to be slower than through reservoirs. Steelhead migration rates upstream from Lower Granite Dam were usually slower in fall than in spring, perhaps because of the onset of overwintering behavior by steelhead in the fall.

Most steelhead with transmitters passed the lower Snake River dams in the fall with a few steelhead overwintering downstream from each of the dams and then passing in the spring. Most steelhead that migrated up the Snake River past the radio receiver site at Asotin, WA, did so in the fall; few steelhead wintered over downstream from Asotin and migrated upstream in the spring. Many steelhead entered the Clearwater River in the fall, but large numbers of steelhead destined for the Clearwater River wintered over in Lower Granite Reservoir, near the confluence of the Snake and Clearwater Rivers and in the Snake River between Lewiston, ID, and Asotin. Steelhead arrived at upper tributary spawning areas mainly in the spring.

Steelhead arrived at tailrace receiver sites at all hours of the day with highest

numbers during daylight hours. Steelhead passed through the fishways of dams mainly during daylight, and few steelhead were recorded passing out the tops of fishways at night. Steelhead passed radio receiver sites at the mouths of major tributaries in largest numbers during daylight hours, but some steelhead were recorded moving at all hours of the day.

Hatchery (clipped adipose fins) and wild (unclipped) steelhead did not differ consistently in time to pass dams, time to migrate through reservoirs and free-flowing rivers, seasonal passage at dams and at most tributary sites, or time of day of passage at dams and through reservoirs and rivers.

Distribution of steelhead with transmitters was similar in all years of the study except 1993. In 1991, 1992 and 1994, about 10% of the steelhead released in the Snake River were last located in the Columbia River or in tributaries to the Columbia River other than the Snake River. In 1993, when steelhead were released at John Day Dam in the Columbia River, 52% were last located outside of the Snake River basin. Distributions of steelhead with transmitters upstream from Lower Granite Dam were similar in all four years of the study. Nineteen to 33% of the steelhead with transmitters were last located in Lower Granite Reservoir each year, 32 to 38% were last located in the Clearwater River basin each year, 15 to 19% were last recorded in the Snake River upstream from Lewiston, and approximately 18 to 20% entered the Salmon River.

Tag recapture information was tabulated during each year. Rates of tag recapture ranged from 26 to 38% during the study with the majority (68%) of the 947 returned tags coming from fisheries. Returns from hatcheries and traps contributed 18 and 5% of all recaptures and 5% were transmitters that were found along river corridors. In years steelhead were released in the vicinity of Ice Harbor Dam 8.3 to 15.9% of the recaptured tags came from the Columbia River below the mouth of the Snake River; 41% of all recaptured tags in 1993 originated from this reach. Between 0.7 and 6.0% of tags recaptured in all study years originated from the Columbia River upstream of the mouth of the Snake River. Recaptures from the Snake River from its mouth to Hell's Canyon Dam ranged from 19.5 to 42% of all recaptures in all years. Between 20 and 41% of all recaptures were in the Clearwater River drainage and 7.8 to 23% were from the Salmon River drainage in all years

Survival estimates for steelhead were calculated for river reaches between the four dams of the lower Snake River. Reach survival estimates were high (mean ~ 95%) for all years with the exception of steelhead released in the summer of 1992. Only 84% of the steelhead released at Charbonneau Park in summer successfully migrated from the release site past Lower Monumental Dam.

Introduction

This report on the migrations of adult steelhead *Oncorhynchus mykiss* through the lower Snake River and into tributaries is Part II of the final report of a multi-year study of adult chinook salmon *O. tshawytscha* and steelhead that passed through the lower Snake River and into tributaries during 1991-1995. Part I of the final report contains general introductory material and methodologies for the entire Snake River study. This report contains material specific to the migrations of adult steelhead.

Primary objectives of the studies reported herein were to monitor passage success and migration rates of adult steelhead past dams and through reservoirs in the lower Snake River. In addition, fallback at dams, seasonal and diel timing of passage at dams and into tributaries, distribution of steelhead into tributaries, and recaptures by anglers or at hatcheries were monitored. Data from the first three years of the study were presented in annual reports (Bjornn et al. 1992; 1994; 1995) and are summarized here along with data collected during 1994 and 1995, the fourth group of steelhead studied.

These studies were undertaken by personnel of the Idaho Cooperative Fish and Wildlife Research Unit (U.S. Geological Survey) from the University of Idaho to insure that passage of steelhead through the lower Snake River was as efficient as possible. Funding was provided by the U.S. Army Corps of Engineers, Bonneville Power Administration, and U.S. Geological Survey.

Radio telemetry was the primary means of monitoring the movements and passage rates of adult steelhead at the dams and during their migrations into tributaries. We used 3- and 7-volt transmitters with a 260 d rated life span, SRX scanning receivers, and digital signal processors (DSP) produced by Lotek Engineering Ltd. SRX receivers were combined with DSPs and underwater coaxial cable antennas to monitor steelhead movements at fishway entrances, exits and within fishways. SRX receivers and Yagi aerial antennas were set up downstream from each of the Snake River dams and at the mouths of major tributaries. In addition to the fixed-site receivers, we searched for steelhead with transmitters in most tributaries by mobile tracking from a truck, and in the Columbia and Snake rivers by boat. Detailed descriptions of the radio telemetry equipment, receiver setups, and antenna locations at each dam are available in Part I of the final report (Bjornn et al. 1998).

The steelhead runs that entered the Snake River during the four years of this study varied in size more than three fold. Part of the variability in run size was the variation in proportion of steelhead counted at Bonneville Dam that were eventually counted at Ice Harbor Dam. Counts of upriver steelhead at Bonneville Dam ranged from 160,767 in 1994 to 313,873 in 1992. The percentage of the steelhead counted at Bonneville Dam that entered the Snake River and were counted at Ice Harbor Dam ranged from 30.8% in 1994-95 (49,450 steelhead) to 53.0% in 1992-93 (166,654 steelhead). The year (1994) with the smallest number of steelhead counted at Bonneville Dam was also the year with the smallest proportion entering the Snake River; the opposite was the case for 1992 when the largest numbers and proportions entered the Snake River.

Methods

Trapping and Tagging

Adult steelhead were trapped at Ice Harbor Dam in the summer and fall of 1991, 1992, and 1994, and at John Day Dam in 1993 (Figure 1), outfitted with transmitters (inserted into the stomach through the

mouth), tagged with a secondary tag and released at or near the dams. The migration of these steelhead was monitored primarily through the lower Snake River and into tributaries. Steelhead from each fish-year were monitored from time of tagging through May of the next spring; for example, steelhead tagged in fall 1994 were monitored through spring 1995.

Steelhead in 1991. - Trapping and tagging of steelhead in the summer and fall of 1991 was similar to that described for chinook salmon (Part I of this final report series). Trapping began in early July and 210 steelhead were trapped, outfitted with transmitters, tagged with an aluminum band on the lower jaw as a secondary tag, and released at Hood Park (12.4 km downstream from Ice Harbor Dam). In mid July, temperatures exceeded 20°C and trapping was suspended (Figure 2). Trapping was resumed in September and continued into November, with 524 additional steelhead trapped, tagged, and released with transmitters. Steelhead trapped in the fall were released at Hood Park (261 fish) and at Charbonneau Park (263 fish) 1.7 km upstream from Ice Harbor Dam. In 1991, the 734 steelhead outfitted with transmitters represented 0.6% of the steelhead that were counted passing Ice Harbor Dam in July, September, and October. Counts at all dams are halted 31 October, so the total number of steelhead that passed the dams each year is unknown.

Steelhead in 1992. - Capture and outfitting of steelhead with transmitters at Ice Harbor Dam in 1992 began at the end of June and continued through mid-July, then resumed again on 1 September when the river cooled and steelhead began migrating over Ice Harbor Dam in large enough numbers to provide the required sample sizes (Figure 2). Water temperatures in the river and the fishways at the dams exceeded 20°C during the latter part of July, August, and early September in 1992. Temperatures at the tops of the fishways ranged from 23 to 25°C during August, and few steelhead entered the Snake River and were counted at Ice Harbor Dam until early September. Trapping and tagging continued through November, 1992.

Four groups of steelhead were released with transmitters and jaw tags in 1992. Fifty-nine steelhead were released at Hood Park and 89 at Charbonneau Park in July. An additional 258 radio-tagged steelhead were released at Hood Park and 288 at Charbonneau Park in the fall, for a total of 694. These tagged fish constituted 0.46% of the steelhead that passed Ice Harbor Dam during July, September, and October.

Steelhead in 1993. - Trapping and tagging of steelhead at John Day Dam in 1993 was similar to that described for chinook salmon in Part I of this final report series. Trapping began 7 July and continued through 6 August, when 251 steelhead were trapped, outfitted with transmitters and secondary tags [visual implant (VI) and coded-wire tags] and released in the lower end of the south-shore fishway. River temperatures exceeded 20°C in the first week of August so trapping was suspended until early September. An additional 633 steelhead were trapped, outfitted with transmitters, and released in the fishway during September, October, and early November for a total of 884 steelhead or 1.2% of the steelhead that passed John Day Dam in July, September, and October (Figure 2).

Steelhead in 1994. - Trapping and tagging operations were moved back to Ice Harbor Dam in 1994. Trapping began on the 16th of September in 1994 and continued until 11 November (Figure 2). A total of 500 hatchery (missing adipose fin) steelhead were trapped at the top of the south-shore fishway, transported to Hood Park, outfitted with transmitters and secondary tags (VI and coded-wire tags) and released.

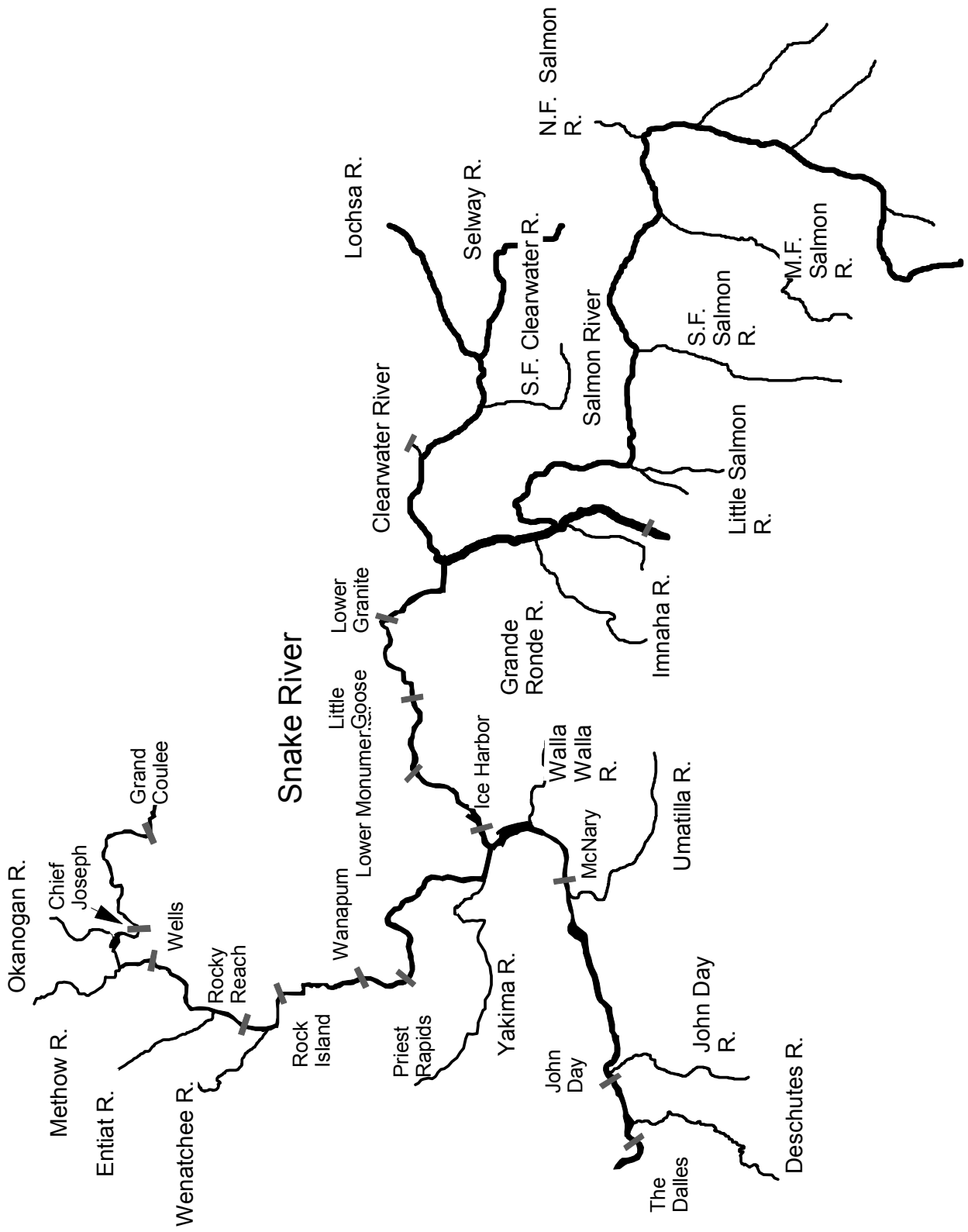

Figure 1. Map of study area extending from The Dalles Dam upstream into the Snake River, with the location of dams and major tributaries.

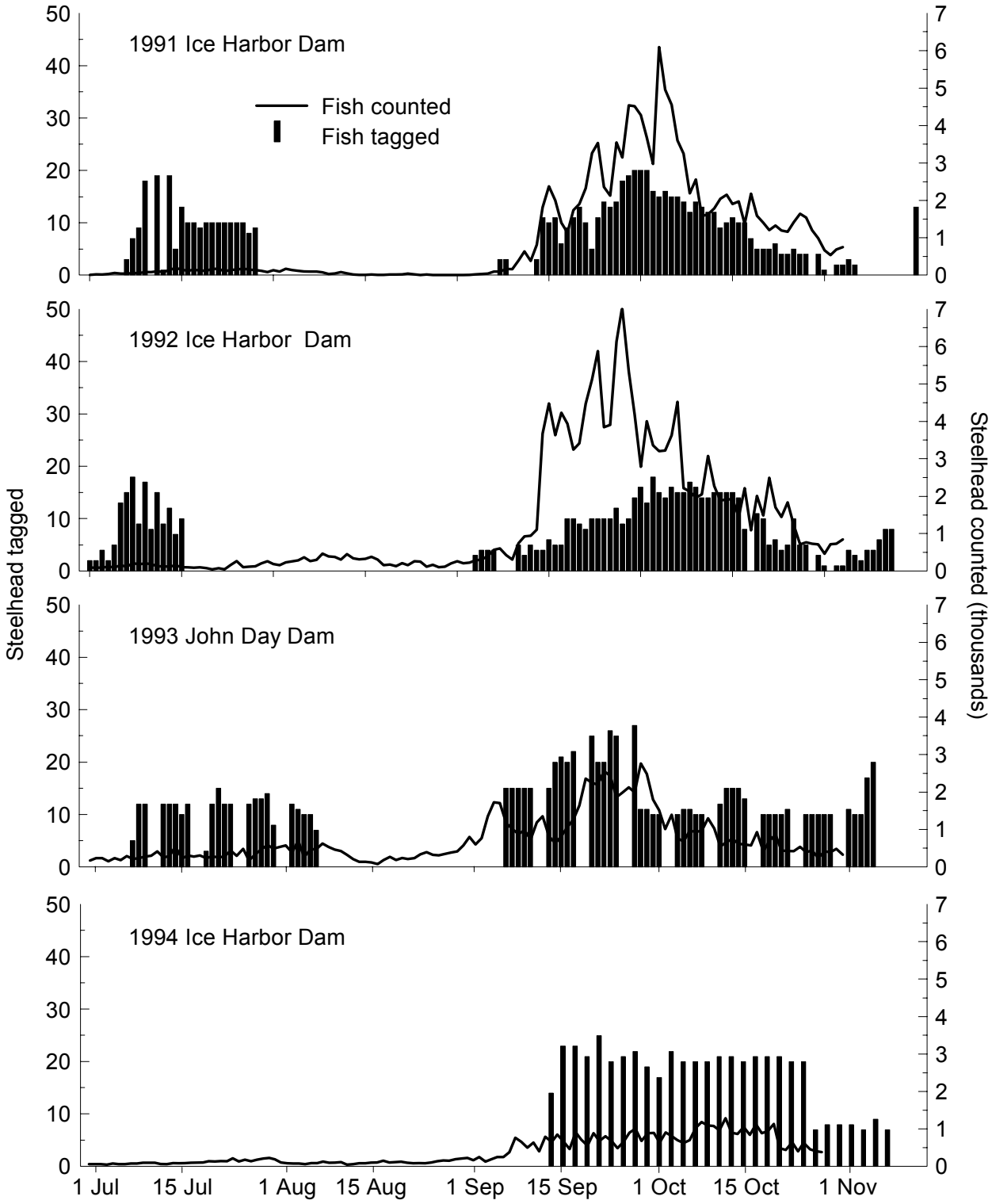

Figure 2. Numbers of steelhead outfitted with radio transmitters each day and the number of steelhead counted at Ice Harbor Dam in 1991, 1992, and 1994, and at John Day Dam in 1993.

Steelhead released with transmitters constituted 1.2% of the steelhead that passed Ice Harbor Dam in September and October. Trapping activities were reduced in 1994 to minimize effects of trap operation on fish passage. In 1994, the trap was operated three to four hours per day on alternating days. In 1991 and 1992, the trap was operated daily for up to 10 h each day.

Transmitter Retention

Transmitter retention rates were calculated by inspecting steelhead recaptured at the adult trap at Lower Granite Dam to see if the transmitter was still in place. Steelhead that should have had a transmitter were identified by secondary tags. Transmitter retention rates in steelhead were similar in all four years of the study. In 1991, 393 steelhead released with transmitters were recaptured at the trap at Lower Granite Dam and 297 (76%) had retained transmitters. In 1992, 296 of 368 (80%) steelhead recaptured at Lower Granite Dam had retained transmitters. In 1993, 328 steelhead released with transmitters at John Day Dam were recaptured at Lower Granite Dam and 269 (82%) had retained transmitters. In 1994, 239 of 323 (74%) recaptured in the adult trap at Lower Granite Dam had retained transmitters.

By comparison, chinook salmon had higher retention rates for transmitters than steelhead. In 1991 and 1992, 96% of chinook salmon released with transmitters at Hood Park and later checked at Lower Granite Dam had retained their transmitters. In 1993, 92% of chinook salmon released in the south fishway at John Day Dam and later checked at Lower Granite Dam had retained their transmitters.

We believe part of the differences in transmitter retention rates between steelhead and chinook salmon were caused by the fishery steelhead were subjected to in all years. There were instances of steelhead recorded at a particular location by mobile tracking that were caught by anglers and their transmitters later found in the river at the same location. We presume these fish regurgitated their transmitters while being caught. Fish known to have lost their transmitters but identified by secondary tags at Lower Granite Dam were included in escapement calculations to Lower Granite Dam, but not in calculations for tributaries upstream from Lower Granite Dam or for travel time analyses.

Passage Success and Migration Rates

Two of the primary objectives of this study were to determine the proportion of adult steelhead that successfully passed the dams and the time required to pass each of the dams in the lower Snake River. Passage of a dam in this report is defined as migrating from the tailrace receiver site (0.5 - 2.7 km downstream from each dam) through the fishway and past the last antenna at the top of the fishway. The proportion of adult steelhead with transmitters that passed each dam was calculated from the number that were known to have entered tailraces and passed dams either by being recorded at tailrace and top of fishway receivers or by being recorded at a site further upstream, including the trap at Lower Granite Dam. Steelhead recovered and identified by a secondary tag at Lower Granite Dam without a functioning transmitter were considered to have migrated successfully.

Times to pass dams were calculated for steelhead that were recorded at both the tailrace receiver site and at the top of a fishway. Time of the last record of the first trip past the tailrace receiver was used as the starting time for passage, and the time of the last record at the top of a fishway was the end of the time to pass. Passage times for steelhead released in fall and passing the dams prior to 31 December were compared using nonparametric analysis of variance. Level of significance was determined using the Bonferroni inequality procedure.

The proportions of adult steelhead with transmitters that successfully migrated through reservoirs and reaches of river were calculated from the number of steelhead recorded exiting the top of a fishway and the number of those steelhead subsequently recorded at sites further upstream. Passage times and migration rates for steelhead migrating through reservoirs and river reaches were also assessed. Reservoir passage times were calculated from the time of the last record at the top of a fishway until a fish arrived at the tailrace receiver at the next dam upstream, or tributary receiver site in the case of Lower Granite Reservoir. Migration rates were defined as the time to pass through reservoirs or river reaches divided by the distance between dams or receiver sites and the receiver at the upper end of the reservoir or reach.

Timing of Steelhead Migration and Distribution into Tributaries

Timing of steelhead movements past dams and into tributaries was monitored both on a diel and seasonal basis. Times and dates of passage at a receiver site were recorded for all steelhead at all fixed-site receivers in the tailraces of dams, fishway exits, and tributary mouths.

Distribution of steelhead into tributaries was assessed with records of steelhead that passed receiver sites at the mouths of tributaries, records of steelhead found in tributaries while mobile tracking, and from recaptures of steelhead at weirs and hatcheries. Because steelhead spawning occurred in the spring when snow blocked access to many tributaries, we were not as efficient at finding spawning steelhead as we were with chinook salmon that spawned in the summer and fall.

Detailed data on the distribution of radio-tagged steelhead in 1991, 1992, and 1993 were presented in previous reports (Bjornn et al. 1992, 1994, and 1995). Data from 1994 are presented here with summaries from previous years.

Passage Success

Passage success of steelhead with transmitters through the lower Snake River depended on the time they were tagged and released, and perhaps the location of release. Steelhead tagged in summer were less likely to pass Lower Granite Dam than steelhead tagged in the fall, and a smaller percentage of the steelhead released downstream from Ice Harbor Dam at Hood Park passed Lower Granite Dam than steelhead released upstream from Ice Harbor Dam at Charbonneau Park (Table 1). Passage success differences for the various groups described above were consistent over the four years and whether the steelhead were trapped at Ice Harbor or John Day dams.

A relatively high percentage (80 to 99%) of the steelhead that passed one dam in the Snake River passed through the next reservoir and over the next dam. The exception to this pattern was for steelhead that were tagged and released in summer at Hood or Charbonneau parks; fewer of those steelhead passed Lower Monumental Dam. Passage from Lower Monumental to Little Goose dams may have been lower than average because the steelhead tagged in summer were group-A steelhead and some were likely destined for Lyons Ferry Hatchery or the Tucannon River.

The percentage of steelhead that passed Lower Granite Dam and were then recorded upstream from Lower Granite Reservoir ranged from 39% to 67% for fish released in summer and 64 to 90% for steelhead released in the fall (Table 1). Steelhead that passed Lower Granite Dam were recorded upstream from Lower Granite Reservoir on receivers that monitored the Clearwater River near its mouth or the Snake River upstream from Asotin, WA, by mobile tracking, or by recaptures by anglers.

Table 1. Numbers of adult steelhead released with radio transmitters at Hood Park (Hood), Charbonneau Park (Char), and John Day Dam; number of steelhead recorded at tailrace receivers, percentage of steelhead released that were known to have passed the tailrace receivers, number recorded on receivers at the top of the fishways, number known to have passed the dams, percentage of steelhead released that were known to have passed the dams, and percentage of steelhead that passed a dam that passed the next dam or receiver site upstream in 1991-1995.

	Release groups					
	1991		1992		1993	1994
	Hood	Char	Hood	Char	John Day	Hood
Steelhead released						
Summer	210	---	59	89	251	---
Fall	261	263	257	288	633	500
Steelhead recorded at tailrace receivers						
Ice Harbor Dam						
Steelhead tagged in summer	88	---	30	49	83	---
Steelhead tagged in fall	169	0	121	17	251	258
Lower Monumental Dam						
Steelhead tagged in summer	53	---	21	41	70	---
Steelhead tagged in fall	113	172	155	200	196	255
Little Goose Dam						
Steelhead tagged in summer	37	---	21	21	50	---
Steelhead tagged in fall	85	132	161	212	241	243
Lower Granite Dam						
Steelhead tagged in summer	18	---	18	21	38	---
Steelhead tagged in fall	66	110	112	144	191	223
Percent known to pass tailrace receivers						
Ice Harbor Dam						
Steelhead tagged in summer	67.6	---	72.9	61.8	44.2	---
Steelhead tagged in fall	82.8	6.8	87.2	9.4	52.8	75.0
Lower Monumental Dam						
Steelhead tagged in summer	46.2	---	61.0	66.3	39.0	---
Steelhead tagged in fall	72.4	93.5	82.1	88.2	48.3	73.8
Little Goose Dam						
Steelhead tagged in summer	36.7	---	54.2	47.2	32.7	---
Steelhead tagged in fall	71.6	89.0	77.4	83.7	47.1	71.2
Lower Granite Dam						
Steelhead tagged in summer	29.5	---	45.8	44.9	28.3	---
Steelhead tagged in fall	64.0	85.6	74.7	78.4	46.0	69.0
Number recorded at top of fishways						
John Day Dam						
Steelhead tagged in summer	---	---	---	---	177	---
Steelhead tagged in fall	---	---	---	---	503	---
McNary Dam						
Steelhead tagged in summer	---	---	---	---	122	---
Steelhead tagged in fall	---	---	---	---	327	---
Ice Harbor Dam						

Table 1. Continued.

	Release groups					
	1991		1992		1993	1994
	Hood	Char	Hood	Char	John Day	Hood
Steelhead tagged in summer	72	---	28	17	76	---
Steelhead tagged in fall	144	2	177	16	259	275
Lower Monumental Dam						
Steelhead tagged in summer	56	---	24	43	70	---
Steelhead tagged in fall	129	176	165	212	234	240
Little Goose Dam						
Steelhead tagged in summer	14	---	19	20	46	---
Steelhead tagged in fall	76	112	152	185	244	261
Lower Granite Dam						
Steelhead tagged in summer	15	---	17	19	40	---
Steelhead tagged in fall	91	136	127	150	225	238
Number known to have passed dam						
John Day Dam						
Steelhead tagged in summer	---	---	---	---	210	---
Steelhead tagged in fall	---	---	---	---	578	---
McNary Dam						
Steelhead tagged in summer	---	---	----	---	156	---
Steelhead tagged in fall	---	---	---	---	398	---
Ice Harbor Dam						
Steelhead tagged in summer	121	---	40	---	105	---
Steelhead tagged in fall	207	---	220	---	318	372
Lower Monumental Dam						
Steelhead tagged in summer	95	---	35	56	95	---
Steelhead tagged in fall	189	240	207	247	304	366
Little Goose Dam						
Steelhead tagged in summer	68	---	28	41	76	---
Steelhead tagged in fall	174	230	194	227	296	351
Lower Granite Dam						
Steelhead tagged in summer	57	---	27	39	69	---
Steelhead tagged in fall	166	223	186	223	288	337
Percent known to have passed dam						
John Day Dam						
Steelhead tagged in summer	---	---	---	---	83.7	---
Steelhead tagged in fall	---	---	---	---	91.3	---
McNary Dam						
Steelhead tagged in summer	---	---	---	---	62.2	---
Steelhead tagged in fall	---	---	---	---	62.9	---
Ice Harbor Dam						
Steelhead tagged in summer	57.6	---	67.8	---	41.8	---
Steelhead tagged in fall	79.3	---	85.6	---	50.2	74.4
Lower Monumental Dam						
Steelhead tagged in summer	45.2	---	59.3	62.9	37.8	---
Steelhead tagged in fall	72.4	91.3	80.5	85.8	48.0	73.2

Table 1. Continued.

	Release groups					
	1991		1992		1993	1994
	Hood	Char	Hood	Char	John Day	Hood
Little Goose Dam						
Steelhead tagged in summer	32.4	---	47.5	46.1	30.3	---
Steelhead tagged in fall	66.7	87.5	75.5	78.8	46.8	70.2
Lower Granite Dam						
Steelhead tagged in summer	27.1	---	45.8	43.8	27.5	---
Steelhead tagged in fall	63.6	84.8	72.4	77.4	45.5	67.4
Percent that passed next upstream dam or site						
John Day Dam						
Steelhead tagged in summer	---	---	---	---	74.3	---
Steelhead tagged in fall	---	---	---	---	68.9	---
McNary Dam						
Steelhead tagged in summer	---	---	---	---	68.6	---
Steelhead tagged in fall	---	---	---	---	79.9	---
Ice Harbor Dam						
Steelhead tagged in summer	80.0	---	87.5	---	90.5	---
Steelhead tagged in fall	91.8	---	94.1	---	95.6	98.4
Lower Monumental Dam						
Steelhead tagged in summer	71.6	---	80.0	73.2	80.0	---
Steelhead tagged in fall	92.1	95.8	93.7	92.7	97.4	95.9
Little Goose Dam						
Steelhead tagged in summer	83.8	---	96.4	95.1	90.8	---
Steelhead tagged in fall	95.4	97.0	95.9	98.2	97.3	96.0
Lower Granite Dam						
Steelhead tagged in summer	50.9	---	66.7	38.5	60.9	---
Steelhead tagged in fall	70.5	72.2	90.3	84.3	74.3	63.5

1991

Of the 210 steelhead released at Hood Park in July, 68% returned upstream to the tailrace of Ice Harbor Dam and 27% eventually passed Lower Granite Dam (Table 1). The relatively low passage rate for steelhead released in July may have been caused by high water temperatures in the river at the time they migrated, operation of the trap in the south-shore fishway, or because they likely were Group A steelhead, some of which were destined for the Tucannon River and Lyons Ferry Hatchery and would not be expected to pass Lower Granite Dam.

Although only about two-thirds of the steelhead released at Hood Park in July returned upstream to Ice Harbor Dam, if they succeeded in passing the dam a second time, 80% went on to pass over Lower Monumental Dam, 72% of those passed Little Goose Dam, 84% of those passed Lower Granite Dam, and 51% of those that passed Lower Granite Dam were recorded in the lower Clearwater River, at the Snake River site near Asotin, or upstream from those sites.

Of the 261 steelhead released at Hood Park in the fall, 83% returned upstream to the Ice Harbor Dam tailrace and 64% of these steelhead passed Lower Granite Dam, more than twice the percentage for steelhead tagged in July. Eighty-five percent of the steelhead released in the fall at

Charbonneau Park passed Lower Granite Dam. Two factors probably reduced the passage success of steelhead released in fall at Hood Park in 1991: the need to reascend Ice Harbor Dam and our operation of the trap in the top of the south-shore fishway. In subsequent years we changed operation of the trap and steelhead were less delayed as they moved up the fishway.

For the steelhead tagged and released at Hood Park in the fall, 83% were known to have returned to Ice Harbor Dam and 79% passed the dam. Of those that passed Ice Harbor Dam, 92% passed Lower Monumental Dam, and 92% of those passed Little Goose Dam. Of those that passed Little Goose Dam, 95% of passed Lower Granite Dam and 71% of those were recorded upstream from Lower Granite Reservoir. Similar passage rates at the dams were observed for steelhead released in the fall at Charbonneau Park, with 72% of those that passed Lower Granite Dam recorded upstream from the reservoir. Two explanations for the lower passage rate through Lower Granite Reservoir compared to the other reservoirs are overwinter mortality and angling mortality. The Clearwater-Snake confluence is an area where many steelhead overwinter and is the site of an active fishery. Anglers remove steelhead with transmitters before they get to the sites upstream from the reservoir, and overwinter mortality reduces the number of steelhead that resume their migrations the next spring.

1992

Passage success of steelhead released in the summer of 1992 was similar to that observed in 1991 (Table 1). Of the 59 steelhead released at Hood Park in the summer, 73% returned upstream to the tailrace at Ice Harbor Dam and 46% eventually passed Lower Granite Dam, about the same rate as in 1991. In 1992, we also released steelhead at Charbonneau Park in the summer, and 44% of 89 steelhead released passed Lower Granite Dam. Fifty-five (62%) of the 89 steelhead released at Charbonneau Park in summer moved downstream, fell back over Ice Harbor Dam and were recorded in the tailrace of the dam. Seventeen of the fallback steelhead were known to have reascended Ice Harbor Dam and were part of the 44% that passed Lower Granite Dam.

Passage success for 257 steelhead released at Hood Park in the fall was similar to the same group released 1991. Eighty-seven percent returned upstream to Ice Harbor Dam, and 72% passed Lower Granite Dam. Of the 288 steelhead released in the fall at Charbonneau Park, 9% were recorded in the tailrace of Ice Harbor Dam and 77% passed Lower Granite Dam. As in 1991, a higher percentage of steelhead released upstream from Ice Harbor Dam migrated successfully past Lower Granite Dam than for steelhead released downstream at Hood Park.

In 1992, steelhead that passed a dam were likely to pass the next dam upstream with the lowest rates for summer-tagged steelhead that passed Lower Monumental Dam (73 to 80%), similar to 1991. Ninety percent of the steelhead released in the fall at Hood Park that passed Lower Granite Dam were recorded upstream from Lower Granite Reservoir. For the other three groups, 39% to 84% of those that passed Lower Granite Dam were recorded upstream from the reservoir. Reasons for the reduced passage out of the Lower Granite Reservoir were likely the same as discussed for 1991.

1993

Of the 251 steelhead released at John Day Dam in the summer of 1993, 84% were known to have passed John Day Dam, 62% McNary Dam, 42% Ice Harbor Dam and 28% passed over Lower Granite Dam (Table 1). The lower percentage of steelhead passing Lower Granite Dam in 1993, was because some steelhead tagged at John Day Dam in the summer are destined for tributaries other than the Snake River.

For the 633 steelhead released in the fall at John Day Dam, 91% passed John Day Dam, 63% passed McNary Dam, 50% passed Ice Harbor Dam and 46% passed over Lower Granite Dam. Many of the steelhead released in the fall were B-group steelhead that were destined for Snake River tributaries.

In 1993, 74% of steelhead released in summer and 69% of steelhead released in fall that passed John Day Dam (210 and 578 steelhead) were subsequently recorded at or upstream from the McNary Dam. Steelhead with transmitters that entered the John Day or Umatilla rivers or were harvested and reported to us from the John Day Reservoir were not included in the calculations. Of the 156 summer-tagged steelhead and 398 fall-tagged steelhead known to have passed McNary Dam, 69% and 80% were recorded at or upstream of the next dam upstream (Ice Harbor or Priest Rapids). Steelhead that entered tributaries of the McNary Reservoir other than the Snake River (Walla Walla and Yakima rivers), that were harvested and reported to us or were recaptured at a hatchery in the Hanford Reach were not included in the calculations. The percentages of steelhead passing John Day and McNary dams that were later recorded at or upstream from the next upstream dam (69% and 80%) were lower than rates for steelhead passing the Snake River dams in the same year (80% to 97%). The reasons for the lower passage rates were not obvious to us.

Steelhead released at John Day Dam in summer or fall that passed Lower Granite Dam had passage rates through Lower Granite Reservoir that were lower than for steelhead released in 1991 and 1992 at Hood or Charbonneau parks; 61% to 74% of the steelhead were recorded upstream from the reservoir.

1994

Passage rates in 1994 were similar to those observed in previous years (Table 1). Of the 500 hatchery steelhead released at Hood Park in the fall of 1994, 75% returned to Ice Harbor Dam, 74% passed Ice Harbor Dam, and 67% passed Lower Granite Dam. In 1991 and 1992, 67% and 72% of steelhead (wild and hatchery combined) released in the fall at Hood Park passed Lower Granite Dam.

As in prior years, steelhead with transmitters that passed a Snake River dam were likely to pass the next dam upstream (96% to 98%). In 1994, 64% of the steelhead that passed Lower Granite Dam were recorded upstream from Lower Granite Reservoir (Table 1).

Time to Pass Dams

Time to pass each of the four lower Snake River dams was monitored in each year of the study. Data for 1991, 1992, and 1993 were presented in previous reports (Bjornn et al. 1992, 1994, 1995) and are summarized here. Data from 1994 have not been presented before and are presented in more detail.

1991

Median times for steelhead with transmitters to pass from tailrace receiver sites to tops of fishways differed significantly (Kruskal-Wallis rank test, $P < 0.05$) among the lower Snake River dams in 1991 for steelhead released in the fall that passed the dams prior to 31 December 1991 (Figure 3). Steelhead took longer to pass Ice Harbor and Lower Granite dams than Lower Monumental and Little Goose dams. Median passage times were 2.0 d at Ice Harbor Dam, 1.1 d at Lower Granite Dam, 0.8 d at Lower Monumental Dam, and 0.5 d at Little Goose Dam (Table 2). The longer passage times at Ice Harbor and Lower Granite dams were likely due to the trapping activities conducted at those two projects. There did not appear to be a difference in time to pass for steelhead released in the summer versus those released during the fall. Steelhead migrating in the spring took

longer to pass the dams than steelhead migrating in the fall but sample sizes were small. Mean times to pass were higher than median times because a few steelhead took several days or weeks to pass the dams.

1992

Times to pass the lower Snake River dams in 1992 for adult steelhead outfitted with radio transmitters were similar to the times observed in 1991 (Table 2). Median times to pass the dams were again longer at Ice Harbor and Lower Granite dams than at Lower Monumental and Little Goose dams. For steelhead released in the fall that passed the dams before 31 December, median passage times ranged from 2.6 d at Ice Harbor Dam to 0.6 d at Little Goose Dam with passage times differing significantly at each of the four dams (Figure 3). There was no apparent difference in times to pass for steelhead released in the summer versus steelhead released in the fall or for steelhead migrating in the fall versus steelhead migrating the next spring.

1993

In 1993, we could better evaluate passage at Ice Harbor Dam because steelhead were trapped, outfitted with transmitters and released at John Day Dam on the Columbia River and were naïve upon arrival at Ice Harbor Dam. Trapping was conducted at Ice Harbor Dam for other studies on a ten-days-on four-days-off cycle. For steelhead released in the fall that passed the dams prior to 31 December 1993, there was no significant difference between passage times at Lower Monumental and Little Goose dams but passage times at Ice Harbor and Lower Granite dams were significantly different from each other and from times at Lower Monumental and Little Goose dams (Figure 3). Median time to pass Lower Granite Dam was slightly longer than the median times observed at the other Snake River dams (Table 2). Passage time at Ice Harbor Dam was faster than at Lower Granite Dam but slower than at Lower Monumental and Little Goose dams. As in previous years, there were no significant differences in times to pass the dams for steelhead released in the summer compared to steelhead released in the fall or for steelhead passing the dams in the spring versus steelhead passing prior to 31 December.

1994

Median times for steelhead released in the fall that passed each of the four lower Snake River dams before 31 December ranged from 1.2 d at Lower Granite Dam to 0.5 d at the other lower Snake River dams (Table 2). Passage time at Lower Granite Dam was significantly (alpha = 0.05) slower than times at the other three dams (Figure 3). Passage times at Ice Harbor, Lower Monumental, and Little Goose dams were not significantly different from each other. For steelhead that wintered over in the lower Snake River and did not pass the dams until after 31 December (mostly in February and March of 1995), the time to pass a dam was highly variable and ranged from a median of 16.5 d at Ice Harbor Dam to less than 3.9 d at the other three dams. Passage times were longer for spring migrating steelhead compared to those that migrated in the fall, although spring sample sizes were small.

Nineteen of the steelhead trapped in 1994 migrated past the dams after 31 December. Ten of the 19 steelhead wintered over downstream from Ice Harbor Dam. Of those ten, eight moved downstream from the release site at Hood Park and were located at least once in the Columbia River during mobile tracking surveys. Of the nine steelhead that did not winter over below Ice Harbor Dam, five spent extended periods of time (from 1.5 to nearly 3 months) below Ice Harbor Dam before moving past the dam and continuing upstream. Of those five, one steelhead spent one month in Ice Harbor Reservoir, one passed Lower Monumental Dam before falling back and spending one

month in Ice Harbor Reservoir, one wintered over in the Lower Monumental Reservoir, one wintered over in the Little Goose Reservoir and tailrace of Lower Granite Dam and one migrated slowly but steadily up through the lower Snake River. Four steelhead passed Ice Harbor Dam soon after release but did not pass the upriver dams before 31 December. Of those four steelhead, two wintered over in Little Goose Reservoir after ascending as far as the tailrace of Lower Granite Dam, one wintered over in Lower Monumental Reservoir below Little Goose Dam, and one moved up to Little Goose Dam, took one month to pass Little Goose Dam, spent two months in Little Goose Reservoir and the tailrace of Lower Granite Dam before falling back to downstream of Ice Harbor Dam.

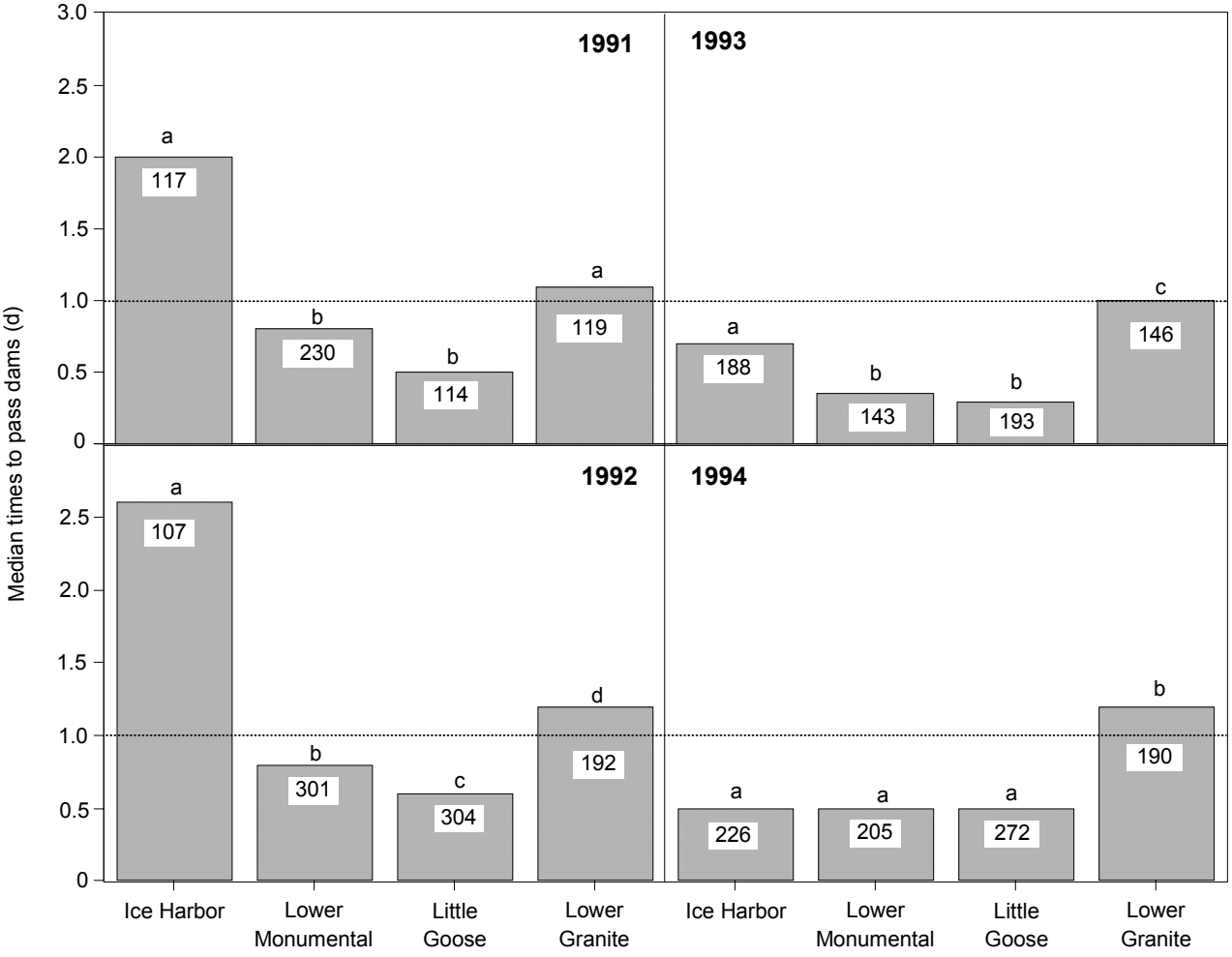

Figure 3. Median passage times of steelhead with transmitters at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams for steelhead released in the fall that passed all four dams before 31 December of the year of release. Sample sizes are the numbers in the bars, and bars with same letters were not significantly different (Kruskal-Wallis rank test, $P < 0.05$).

Table 2. Mean and median times (d) for adult steelhead with radio transmitters to pass the lower Snake River dams for steelhead released in summer or fall that migrated past the dams in before 31 December or after 31 December, 1991-1995. Median values with adequate sample sizes in bold type.

	1991-92			1992-93			1993-94			1994-95		
	n	Mean	Med.	n	Mean	Med.	n	Mean	Med.	n	Mean	Med.
Ice Harbor Dam												
Summer release												
Fall passage	48	5.3	**1.8**	22	21.7	**1.8**	69	3.2	**1.1**	--	---	---
Spring passage	0	---	---	0	---	---	0	---	---	--	---	---
Fall release												
Fall passage	117	7.7	**2.0**	107	8.2	**2.6**	188	1.5	**0.7**	226	1.1	**0.5**
Spring passage	4	48.4	43.6	4	1.9	1.6	28	33.0	**0.4**	9	39.0	16.5
Lower Monumental Dam												
Summer release												
Fall passage	45	1.4	**0.7**	57	4.5	**0.8**	65	1.6	**0.9**	---	---	---
Spring passage	0	---	---	0	---	---	1	0.4	---	---	---	---
Fall release												
Fall passage	230	1.6	**0.8**	301	1.9	**0.8**	143	0.8	**0.4**	205	0.8	**0.5**
Spring passage	9	20.9	0.5	12	9.5	0.7	27	7.3	0.5	7	4.3	2.6
Little Goose Dam												
Summer release												
Fall passage	8	3.1	0.3	33	1.5	0.5	41	1.8	0.6	---	---	---
Spring passage	1	24.5	---	1	0.2	---	1	0.4	---	---	---	---
Fall release												
Fall passage	114	1.1	**0.5**	304	2.2	**0.6**	193	0.8	**0.3**	222	1.3	**0.5**
Spring passage	12	27.5	9.7	18	1.9	1.3	34	14.3	0.5	12	12.5	1.9
Lower Granite Dam												
Summer release												
Fall passage	9	3.6	1.6	30	3.7	1.2	34	2.4	1.3	---	---	---
Spring passage	0	---	---	3	89.4	34.1	0	---	---	---	---	---
Fall release												
Fall passage	119	1.9	**1.1**	192	2.6	**1.2**	146	1.6	**1.0**	190	1.5	**1.2**
Spring passage	12	47.9	17.9	17	28.5	1.5	28	4.2	1.5	12	24.3	3.9

The steelhead then reascended to the tailrace of Lower Granite Dam where it spent three weeks before passing Lower Granite Dam and moving upriver past the receiver site at Asotin.

One of the 19 steelhead that did not pass the dams prior to 31 December appeared to migrate slowly but continuously up through the lower Snake River during the winter and spring. The other 18 steelhead appeared to stop upstream migration for extended periods. Fourteen of the 18 steelhead resumed their migration in mid- to late February. The other four steelhead resumed their migrations in late January, early February, late March, and early April.

Similar to previous years, median passage time for steelhead that migrated through the lower Snake River in the fall of 1994 was longer at Lower Granite Dam than at Lower Monumental and Little Goose dams. In previous years, the median passage time at Ice Harbor Dam was also longer than at Lower Monumental and Little

Goose dams; this was not the case in 1994. As discussed by Bjornn et al. (1995), it is likely that the longer median passage times observed at Lower Granite Dam and in previous years at Ice Harbor Dam were due to the trapping activities at the two dams. This is supported by the non-significant difference in median passage times for steelhead passing Ice Harbor, Lower Monumental and Little Goose dams in 1994 when trapping activities at Ice Harbor Dam were minimal compared to previous years (trap was operated 3 to 4 h on alternating days).

The distributions of passage times for steelhead in 1994 were similar to those observed in previous years and similar at three of the four lower Snake River dams for steelhead released at Hood Park in the fall and migrating past lower Snake River dams in the fall of 1994 (Figure 4); most steelhead passed the dams within 24 h and a high percentage (91-93%) passed within 48 h. At Lower Granite Dam, 78% of the steelhead that passed did so within 48 h and all passed in less than 7 d.

Steelhead that passed the lower Snake River dams in spring 1995 passed the dams at a slower rate than steelhead that migrated in fall 1994 (Figure 5). Nine steelhead with transmitters passed Ice Harbor Dam in the spring of 1995, and only one passed the dam in < 48 h. Of the 7 steelhead that passed Lower Monumental Dam in the spring of 1995, 2 did so in less than 48 h. One fish first approached Lower Monumental Dam in January and took 85.7 d to pass. Twelve steelhead passed Little Goose and Lower Granite dams in the spring of 1995, of which 6 passed Little Goose Dam and 5 passed Lower Granite Dam in less than 48 h.

Passage Rates for Hatchery Versus Wild Steelhead

Median passage times at the four lower Snake River dams were longer for wild (lacking fin clips) than hatchery steelhead (Table 3), but the differences were not significant.

Migration Times and Rates Through Reservoirs

Migration times and rates for steelhead with transmitters through the lower Snake River reservoirs were measured in each year of the study. Times and rates were calculated for steelhead released in July and August (summer) and compared to steelhead released in September, October and November (fall), that passed through the reservoirs in the summer, in fall prior to 31 December, while wintering over, and in the spring (after 31 December). Migration times and rates were variable over all seasons and reservoirs, but consistent within seasons and reservoirs when adequate numbers of steelhead migrants existed. Sample sizes were small for spring-migrating steelhead, but passage times and rates were similar for specific reservoirs across all years.

1991

Migration times were a function of the length of the reservoirs (46 to 60 km), location of the reservoir (wintering areas) and season of the year. Median times varied from 0.9 to 109 d for steelhead depending on reservoir and season of migration (Table 4). Steelhead that migrated through the three lower reservoirs during the summer, fall, or spring had median times that ranged from 0.9 to 4.7 d. Steelhead that migrated in winter, in more than one season, or wintered over in Lower Granite Reservoir had the longest migration times.

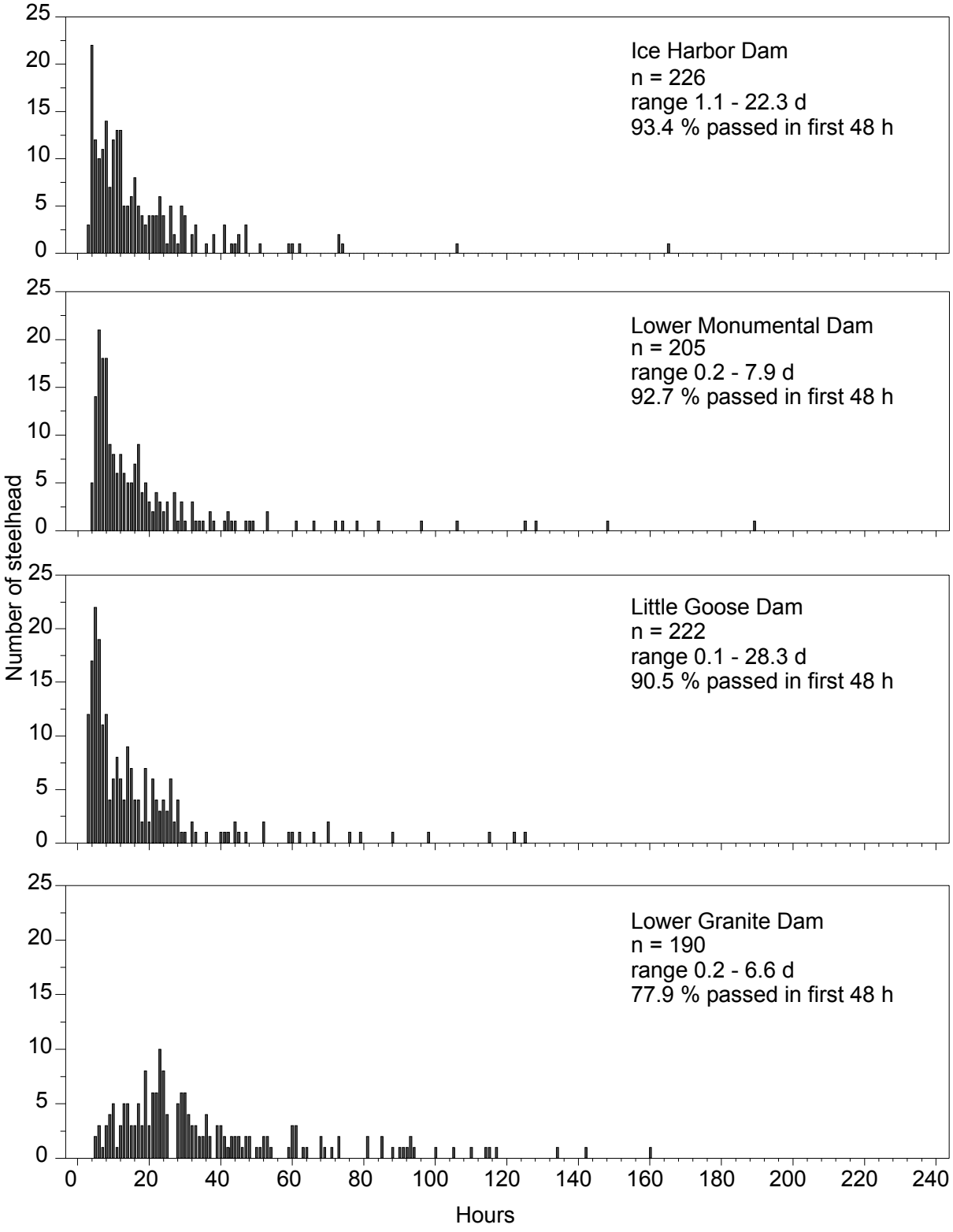

Figure 4. Frequency distribution of passage times for steelhead released in the fall with transmitters at Hood Park that passed dams in the lower Snake River before 31 December in 1994.

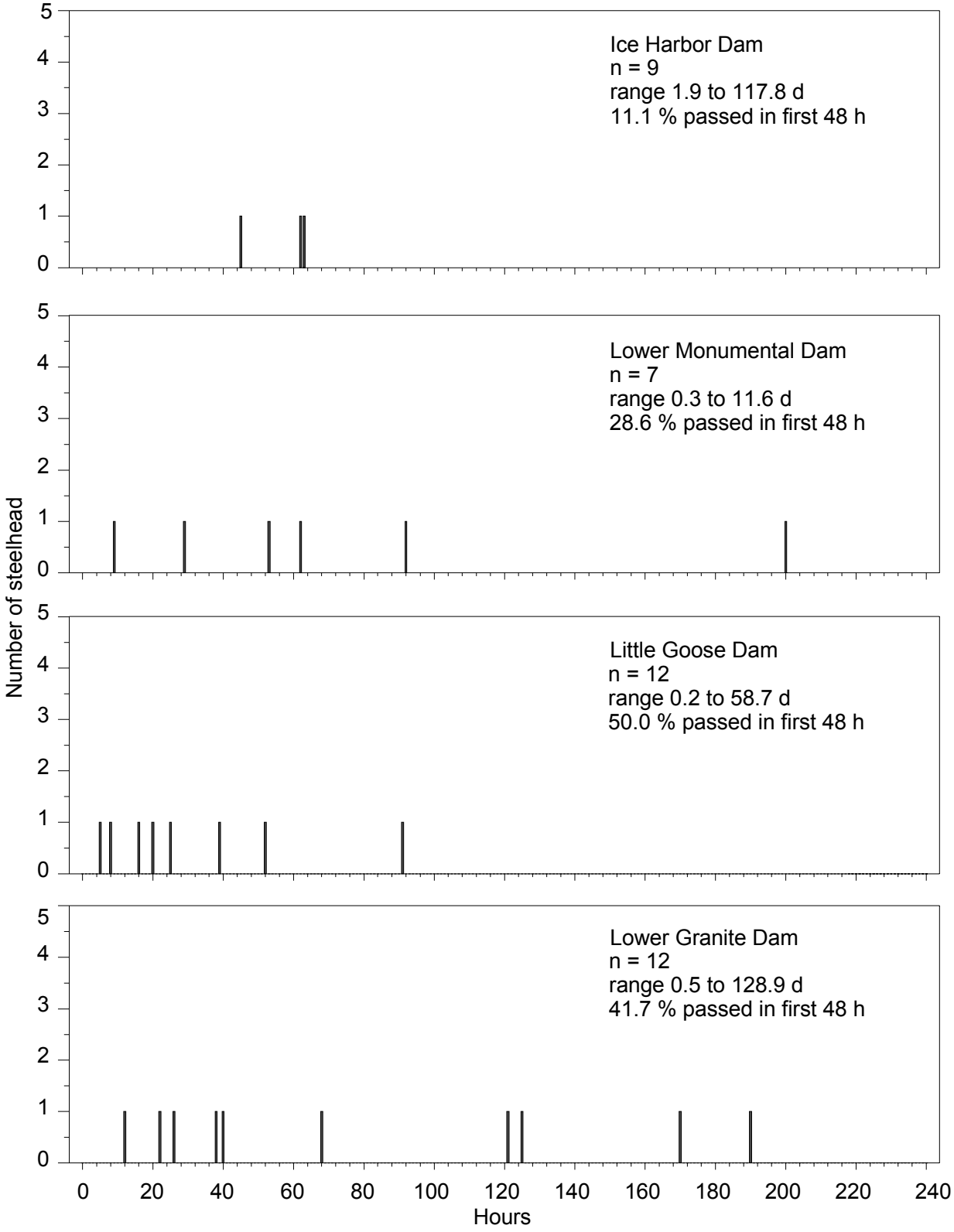

Figure 5. Frequency distribution of passage times for steelhead released in the fall of 1994 with transmitters at Hood Park that passed dams in the lower Snake River after 31 December.

Table 3. Number of steelhead (hatchery and wild) with transmitters that passed lower Snake River dams from summer 1991 to spring 1995 with their mean and median passage times (d), and 95% confidence intervals for median values. Sample sizes were determined by the number of fish in each group that had detections at tailrace and top-of-ladder receiver sites.

	Hatchery				Wild			
Dam passed	n	Mean	Median	95% CI	n	Mean	Median	95%CI
Ice Harbor	641	3.56	0.80	0.72 - 0.91	173	6.37	1.24	1.11 - 1.61
Lower Mon.	739	1.76	0.56	0.50 - 0.62	297	2.29	0.65	0.53 - 0.76
Little Goose	656	2.42	0.48	0.44 - 0.55	252	2.63	0.58	0.47 - 0.69
Lower Granite	543	3.83	1.23	1.16 - 1.33	179	6.81	1.33	0.98 - 1.35

Migration rates (distance migrated/median migration time) for steelhead that migrated through the lower Snake River reservoirs in 1991 ranged from 3 to 55 km/d (Table 4). Steelhead released during the summer that migrated through the reservoirs during the summer had migration rates of 10 to 38 km/d. Steelhead released in the fall that migrated in the fall migrated at rates of 17 to 45 km/d. Migration rates of steelhead were fastest in the Ice Harbor and Little Goose reservoirs in 1991 and slowest in Lower Monumental and Lower Granite reservoirs (Figure 6).

Migration rates through Lower Granite Reservoir differed depending on where the fish were headed and the season of migration. Steelhead released in the fall that crossed Lower Granite Dam and were recorded on the Clearwater River receiver prior to 31 December migrated at a slower rate through the reservoir (3.0 km/d, n=45) than those that crossed the dam the next spring (41.9 km/d, n=11).

Steelhead that continued up the Snake River and were recorded at the Asotin receiver migrated faster through Lower Granite Reservoir than steelhead recorded in the Clearwater River regardless of season of migration. None of the summer-released steelhead passed the Asotin site in the summer, but those that passed the Asotin site in the fall had a migration rate of 14.9 km/d (n=7). The one summer-released steelhead that passed the Asotin site the following spring had a migration rate of 40.1 km/d. Fall-released steelhead that continued up the Snake River after passing Lower Granite Dam and were recorded at the Asotin site in the fall had a migration rate of 20.0 km/d (n=94), and those recorded at the Asotin site the following spring had a rate of 42.7 km/d (n=2). Most steelhead passed Lower Granite Dam in the fall and those destined for Snake River tributaries upstream from the Clearwater River migrated through the reservoir with minimal delay to upriver areas where they overwintered.

There was little movement once steelhead entered the overwintering phase of their life cycle as noted by McMaster et al. (1977). Most steelhead moved past the dams by late fall, but then wintered over in the upper end of Lower Granite Reservoir, lower Clearwater River, Snake River upstream from the reservoir or the lower Grande Ronde and Salmon rivers before they continued their migration into the tributaries in March and April.

1992

Steelhead migration rates in 1992 were similar to rates observed in 1991 (Table 4, Figure 6). Steelhead released in summer that migrated through the reservoirs in summer had migration rates of 10.0 to 35.2 km/d.

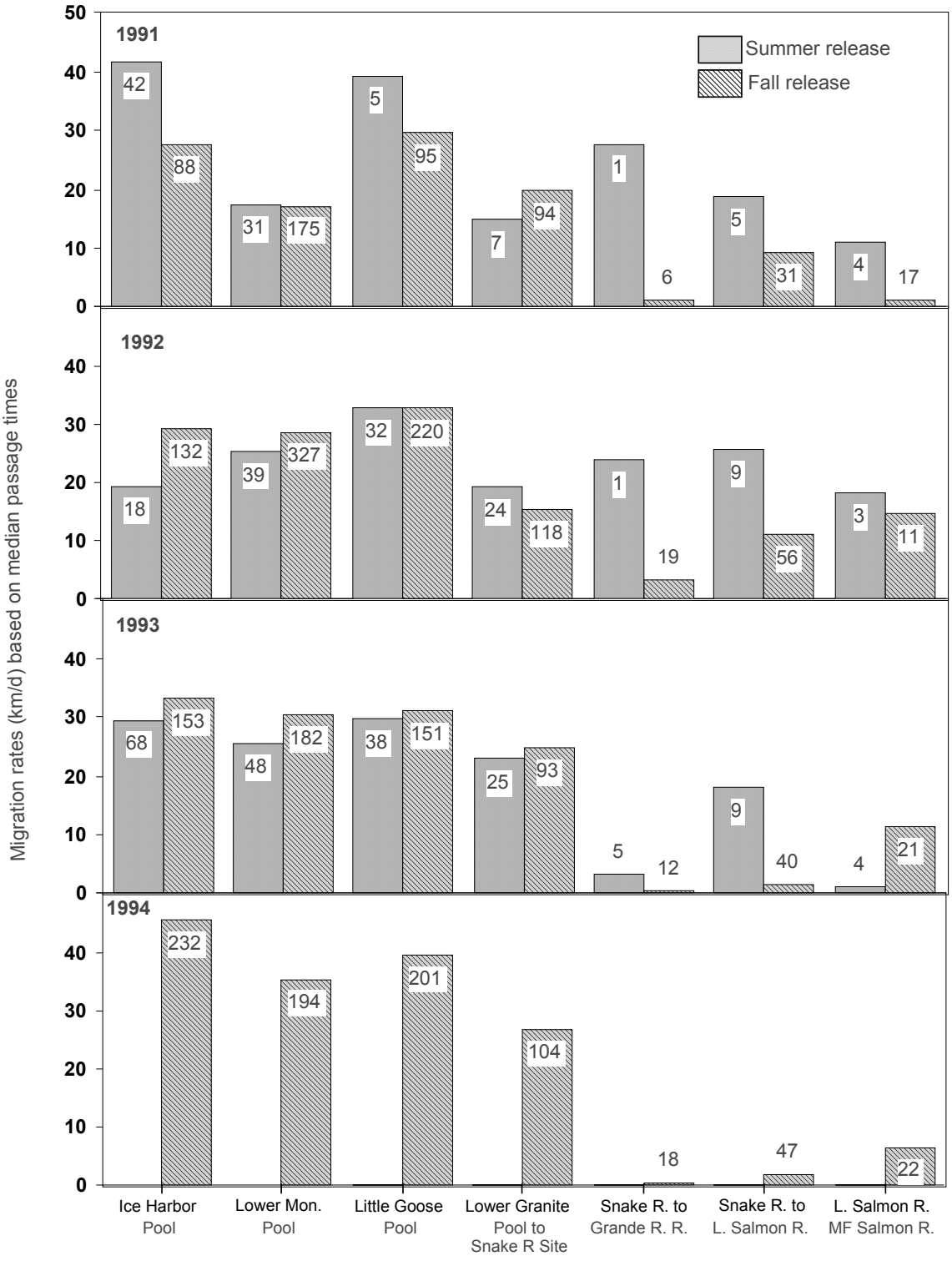

Figure 6. Migration rates of steelhead through lower Snake River reservoirs and free-flowing reaches of rivers upstream from the reservoirs for steelhead released in the summer and fall that migrated through the reach before 31 December of the year they were released. Numbers in bars are the number of steelhead in sample.

Table 4. Number of steelhead, mean or median days to migrate through reservoirs and free-flowing reaches, and rate of migration (based on median days) for steelhead with transmitters released in summer or fall that migrated through the reservoirs or reaches in summer (through 31 August), summer and fall (through 31 December), fall (1 September through 31 December), after wintering over in reservoirs or reaches (entered reach before 1 January and recorded at next upstream site after 1 January), and in the spring (after 1 January) in 1991-1995.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
		Summer		Wintered			Summer		Wintered	
Release season: Summer	Summer	\fall	Fall	over	Spring	Summer	/fall	Fall	over	Spring
1991										
Summer release										
Number of fish	40	48	0	0	0	9	2	31	0	0
Mean days	4.7	71.6	---	---	---	3.8	76.0	4.1	---	---
Median days	1.4	68.2	---	---	---	1.3	76.0	1.1	---	---
Kilometers/d	8.4	0.2	---	---	---	38.4	0.7	45.4	---	---
Fall release										
Number of fish	0	0	165	4	0	0	0	88	2	4
Mean days	---	---	10.4	163.3	---	---	---	5.6	157.7	1.3
Median days	---	---	3.2	180.2	---	---	---	1.8	157.7	0.9
Kilometers/d	---	---	3.7	0.1	---	---	---	27.7	0.3	55.4
1992										
Summer release										
Number of fish	16	14	0	0	0	4	0	14	1	0
Mean days	4.6	80.6	---	---	---	3.4	---	3.2	280.2	---
Median days	1.1	77.3	---	---	---	3.6	---	2.5	280.2	---
Kilometers/d	10.6	0.2	---	---	---	13.9	---	20.0	0.2	---
Fall release										
Number of fish	0	0	115	6	0	0	0	132	3	8
Mean days	---	---	12.3	169.6	---	---	---	2.7	69.3	6.4
Median days	---	---	7.1	172.2	---	---	---	1.7	60.1	1.0
Kilometers/d	---	---	1.6	0.1	---	---	---	29.4	0.8	49.9
1993										
Summer release										
Number of fish	0	0	0	0	0	53	1	14	0	1
Mean days	---	---	---	---	---	2.1	10.3	1.9	---	1.1
Median days	---	---	---	---	---	1.7	10.3	1.5	---	1.1
Kilometers/d	---	---	---	---	---	29.4	4.8	33.3	---	45.4
Fall release										
Number of fish	0	0	0	0	0	0	0	153	5	23
Mean days	---	---	---	---	---	---	---	2.9	75.4	2.0
Median days	---	---	---	---	---	---	---	1.5	34.0	1.2
Kilometers/d	---	---	---	---	---	---	---	33.3	1.5	41.6
1994										
Fall release										
Number of fish	0	0	249	9	0	0	0	231	2	7
Mean days	---	---	9.1	118.7	---	---	---	1.6	21.2	5.1
Median days	---	---	1.9	118.8	---	---	---	1.1	21.2	3.1
Kilometers/d	---	---	6.2	0.1	---	---	---	45.4	2.4	16.1

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
1991										
Summer release										
Number of fish	0	0	0	0	0	5	0	26	1	0
Mean days	---	---	---	---	---	6.2	---	3.3	88.3	---
Median days	---	---	---	---	---	4.7	---	2.4	88.3	---
Kilometers/d	---	---	---	---	---	9.7	---	19.1	0.5	---
Fall release										
Number of fish	0	0	172	0	0	0	0	175	5	7
Mean days	---	---	5.7	---	---	---	---	3.2	90.8	1.9
Median days	---	---	2.3	---	---	---	---	2.7	76.3	1.7
Kilometers/d	---	---	21.0	---	---	---	---	17.0	0.6	26.9
1992										
Summer release										
Number of fish	29	11	0	1	0	8	5	26	1	0
Mean days	4.3	95.5	---	284.1	---	2.5	59.5	5.0	106.9	---
Median days	2.6	95.3	---	284.1	---	1.3	59.1	1.8	106.9	---
Kilometers/d	18.5	0.5	---	0.2	---	35.2	0.8	25.4	0.4	---
Fall release										
Number of fish	0	0	195	3	0	0	0	335	1	8
Mean days	---	---	5.7	175.2	---	---	---	2.0	8.0	1.0
Median days	---	---	3.0	176.9	---	---	---	1.6	8.0	0.9
Kilometers/d	---	---	16.1	0.3	---	---	---	28.6	5.7	50.9
1993										
Summer release										
Number of fish	0	0	0	0	0	28	6	14	0	1
Mean days	---	---	---	---	---	2.2	35.4	1.4	---	1.1
Median days	---	---	---	---	---	1.8	36.8	1.2	---	1.1
Kilometers/d	---	---	---	---	---	25.4	1.2	38.2	---	41.6
Fall release										
Number of fish	0	0	0	0	0	0	0	182	3	30
Mean days	---	---	---	---	---	---	---	1.8	39.1	1.4
Median days	---	---	---	---	---	---	---	1.5	14.3	1.1
Kilometers/d	---	---	---	---	---	---	---	30.5	3.2	41.6
1994										
Fall release										
Number of fish	0	0	0	0	0	0	0	197	1	8
Mean days	---	---	---	---	---	---	---	2.1	50.0	3.0
Median days	---	---	---	---	---	---	---	1.3	50.0	2.0
Kilometers/d	---	---	---	---	---	---	---	35.2	0.9	22.9
1991										
Summer release										
Number of fish	0	0	5	1	0	0	0	0	0	0
Mean days	---	---	1.8	87.8	---	---	---	---	---	---

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
Spring										
Median days	---	---	1.5	87.8	---	---	---	---	---	---
Kilometers/d	---	---	39.4	0.7	---	---	---	---	---	---
Fall release										
Number of fish	0	0	95	2	8	0	0	45	17	11
Mean days	---	---	3.7	113.3	1.7	---	---	24.5	114.4	1.6
Median days	---	---	2.0	113.3	1.4	---	---	19.8	112.7	1.4
Kilometers/d	---	---	29.6	0.5	42.2	---	---	3.0	0.5	41.9
1992										
Summer release										
Number of fish	8	0	25	1	1	1	0	1	1	0
Mean days	2.1	---	2.0	54.7	3.2	3.2	---	30.0	101.6	---
Median days	2.0	---	1.8	54.7	3.2	3.2	---	30.0	101.6	---
Kilometers/d	29.6	---	32.8	1.1	18.5	18.3	---	2.0	0.6	---
Fall release										
Number of fish	0	0	228	0	15	0	0	48	26	18
Mean days	---	---	2.8	---	1.3	---	---	7.2	109.6	1.7
Median days	---	---	1.9	---	1.0	---	---	4.5	109.4	1.3
Kilometers/d	---	---	31.1	---	59.1	---	---	13.0	0.5	45.2
1993										
Summer release										
Number of fish	20	2	16	0	0	5	1	0	1	0
Mean days	2.4	25.2	2.6	---	---	11.2	16.4	---	85.5	---
Median days	1.9	25.2	1.8	---	---	8.4	16.4	---	85.5	---
Kilometers/d	31.1	2.3	32.8	---	---	7.0	3.6	---	0.7	---
Fall release										
Number of fish	0	0	151	4	29	0	0	33	20	21
Mean days	---	---	2.4	83.4	1.4	---	---	8.8	101.8	1.9
Median days	---	---	1.9	92.1	1.3	---	---	4.3	105.9	1.6
Kilometers/d	---	---	31.1	0.6	45.5	---	---	13.7	0.6	36.7
1994										
Fall release										
Number of fish	0	0	207	0	12	0	0	49	29	7
Mean days	---	---	2.2	---	2.1	---	---	13.2	91.6	1.4
Median days	---	---	1.5	---	1.7	---	---	4.1	87.6	1.4
Kilometers/d	---	---	39.4	---	34.8	---	---	14.3	0.7	41.9
1991										
Summer release										
Number of fish	0	0	7	0	1	0	0	1	0	0
Mean days	---	---	6.3	---	1.6	---	---	1.3	---	---
Median days	---	---	4.3	---	1.6	---	---	1.3	---	---
Kilometers/d	---	---	14.9	---	40.1	---	---	27.7	---	---

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
Fall release										
Number of fish	0	0	94	0	2	0	0	4	2	1
Mean days	---	---	5.1	---	1.5	---	---	18.4	145.9	0.6
Median days	---	---	3.2	---	1.5	---	---	20.6	145.9	0.6
Kilometers/d	---	---	20.0	---	42.7	---	---	1.7	0.2	60.0
1992										
Summer release										
Number of fish	1	0	23	0	2	0	0	1	0	1
Mean days	6.3	---	5.0	---	2.2	---	---	1.5	---	4.7
Median days	6.3	---	3.3	---	2.2	---	---	1.5	---	4.7
Kilometers/d	10.2	---	19.4	---	29.1	---	---	24.0	---	7.7
Fall release										
Number of fish	0	0	112	6	3	0	0	9	10	1
Mean days	---	---	5.8	96.9	1.3	---	---	4.7	106.3	0.8
Median days	---	---	4.0	95.4	1.1	---	---	4.0	114.2	0.8
Kilometers/d	---	---	16.0	0.7	58.3	---	---	9.0	0.3	45.0
1993										
Summer release										
Number of fish	3	3	18	1	1	0	1	3	1	1
Mean days	3.9	51.4	5.0	134.2	1.4	---	9.8	8.9	59.7	0.8
Median days	3.2	45.3	2.1	134.2	1.4	---	9.8	10.7	59.7	0.8
Kilometers/d	20.0	1.4	30.5	0.5	45.8	---	3.7	3.4	0.6	45.0
Fall release										
Number of fish	0	0	91	2	9	0	0	6	5	4
Mean days	---	---	4.4	114.1	3.5	---	---	29.6	112.0	2.9
Median days	---	---	2.5	114.1	2.2	---	---	21.0	97.6	1.4
Kilometers/d	---	---	25.6	0.6	29.1	---	---	1.7	0.4	25.7
1994										
Fall release										
Number of fish	0	0	104	0	5	0	0	8	10	0
Mean days	---	---	4.0	---	2.6	---	---	22.6	83.0	---
Median days	---	---	2.3	---	2.8	---	---	8.5	77.5	---
Kilometers/d	---	---	27.9	---	22.9	---	---	4.2	0.5	---
Summer release										
Number of fish	0	0	5	0	0	0	0	0	0	0
Mean days	---	---	14.6	---	---	---	---	---	---	---
Median days	---	---	10.8	---	---	---	---	---	---	---
Kilometers/d	---	---	18.9	---	---	---	---	---	---	---
1991										
Fall release										
Number of fish	0	0	24	7	1	0	0	0	2	3
Mean days	---	---	18.3	124.5	5.1	---	---	---	163.1	22.3
Median days	---	---	14.1	114.6	5.1	---	---	---	163.1	27.4
Kilometers/d	---	---	14.5	1.8	40.1	---	---	---	0.8	4.8

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
1992										
Summer release										
Number of fish	0	0	8	1	1	0	0	0	0	0
Mean days	---	---	9.7	146.1	6.8	---	---	---	---	---
Median days	---	---	7.8	146.1	6.8	---	---	---	---	---
Kilometers/d	---	---	26.2	1.4	30.1	---	---	---	---	---
Fall release										
Number of fish	0	0	38	16	4	0	0	0	1	4
Mean days	---	---	16.4	145.6	15.1	---	---	---	183.1	18.1
Median days	---	---	14.5	146.1	11.3	---	---	---	183.1	21.1
Kilometers/d	---	---	14.1	1.4	18.1	---	---	---	0.7	6.2
1993										
Summer release										
Number of fish	0	2	6	1	0	0	0	0	0	0
Mean days	---	30.2	11.3	146.3	---	---	---	---	---	---
Median days	---	30.2	9.7	146.3	---	---	---	---	---	---
Kilometers/d	---	6.8	21.1	1.4	---	---	---	---	---	---
Fall release										
Number of fish	0	0	13	26	2	0	0	0	0	0
Mean days	---	---	14.3	141.7	11.1	---	---	---	---	---
Median days	---	---	14.9	139.5	11.1	---	---	---	---	---
Kilometers/d	---	---	13.7	1.5	18.4	---	---	---	---	---
1994										
Fall release										
Number of fish	0	0	16	31	3	0	0	0	0	0
Mean days	---	---	12.3	120.8	9.9	---	---	---	---	---
Median days	---	---	11.7	121.2	7.3	---	---	---	---	---
Kilometers/d	---	---	17.5	1.7	28.0	---	---	---	---	---
1991										
Summer release										
Number of fish	0	0	4	0	0	0	0	0	0	0
Mean days	---	---	17.3	---	---	---	---	---	---	---
Median days	---	---	16.3	---	---	---	---	---	---	---
Kilometers/d	---	---	11.1	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	2	14	1	0	0	0	3	0
Mean days	---	---	22.5	125.6	16.0	---	---	---	156.9	---
Median days	---	---	22.5	127.3	16.0	---	---	---	154.7	---
Kilometers/d	---	---	8.0	1.4	11.3	---	---	---	1.6	---
1992										
Summer release										
Number of fish	0	0	3	0	1	0	0	3	0	1
Mean days	---	---	9.8	---	10.3	---	---	19.2	---	11.9

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
Median days	---	---	9.8	---	10.3	---	---	17.4	---	11.9
Kilometers/d	---	---	18.4	---	17.5	---	---	13.9	---	20.3
Fall release										
Number of fish	0	0	1	3	7	0	0	0	6	4
Mean days	---	---	12.3	182.9	10.9	---	---	---	157.4	11.7
Median days	---	---	12.3	179.3	10.0	---	---	---	158.3	10.9
Kilometers/d	---	---	14.7	1.0	18.1	---	---	---	1.5	22.1
1993										
Summer release										
Number of fish	0	0	1	3	0	0	0	0	3	0
Mean days	---	---	1.2	161.9	---	---	---	---	172.7	---
Median days	---	---	1.2	160.8	---	---	---	---	172.9	---
Kilometers/d	---	---	150.6	1.1	---	---	---	---	1.4	---
Fall release										
Number of fish	0	0	0	7	15	0	0	0	6	12
Mean days	---	---	---	148.8	14.1	---	---	---	152.6	19.9
Median days	---	---	---	148.9	14.5	---	---	---	154.7	19.8
Kilometers/d	---	---	---	1.2	12.5	---	---	---	1.6	12.2
1994										
Fall release										
Number of fish	0	0	1	8	15	0	0	0	8	11
Mean days	---	---	41.2	139.3	20.0	---	---	---	143.1	26.6
Median days	---	---	41.2	139.8	19.9	---	---	---	144.1	23.2
Kilometers/d	---	---	4.4	1.3	9.1	---	---	---	1.7	10.4
1991										
Summer release										
Number of fish	0	0	0	0	0	0	0	0	0	0
Mean days	---	---	---	---	---	---	---	---	---	---
Median days	---	---	---	---	---	---	---	---	---	---
Kilometers/d	---	---	---	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	0	0	8	0	0	0	1	1
Mean days	---	---	---	---	15.9	---	---	---	149.5	3.8
Median days	---	---	---	---	6.9	---	---	---	149.5	3.8
Kilometers/d	---	---	---	---	8.8	---	---	---	0.8	29.7
1992										
Summer release										
Number of fish	0	0	2	0	0	0	0	0	0	0
Mean days	---	---	6.7	---	---	---	---	---	---	---
Median days	---	---	6.7	---	---	---	---	---	---	---
Kilometers/d	---	---	9.0	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	0	0	3	0	0	0	3	4

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
Mean days	---	---	---	---	4.8	---	---	---	115.3	13.5
Median days	---	---	---	---	3.9	---	---	---	128.6	14.2
Kilometers/d	---	---	---	---	15.5	---	---	---	0.9	7.9
1993										
Summer release										
Number of fish	0	0	0	1	3	0	0	0	0	0
Mean days	---	---	---	149.0	10.0	---	---	---	---	---
Median days	---	---	---	149.0	12.1	---	---	---	---	---
Kilometers/d	---	---	---	0.4	5.0	---	---	---	---	---
Fall release										
Number of fish	0	0	0	0	19	0	0	0	1	5
Mean days	---	---	---	---	5.9	---	---	---	140.8	24.2
Median days	---	---	---	---	4.9	---	---	---	140.8	28.2
Kilometers/d	---	---	---	---	12.3	---	---	---	0.8	4.0
1994										
Fall release										
Number of fish	0	0	0	1	19	0	0	0	6	6
Mean days	---	---	---	84.1	6.9	---	---	---	84.2	26.3
Median days	---	---	---	84.1	6.0	---	---	---	83.5	26.4
Kilometers/d	---	---	---	0.7	10.1	---	---	---	1.3	4.3
1991										
Summer release										
Number of fish	0	0	0	0	0	0	0	0	0	0
Mean days	---	---	---	---	---	---	---	---	---	---
Median days	---	---	---	---	---	---	---	---	---	---
Kilometers/d	---	---	---	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	0	2	2	0	0	0	0	1
Mean days	---	---	---	124.0	26.0	---	---	---	---	14.9
Median days	---	---	---	124.0	26.0	---	---	---	---	14.9
Kilometers/d	---	---	---	1.2	5.8	---	---	---	---	10.3
1992										
Summer release										
Number of fish	0	0	0	0	0	0	0	0	0	0
Mean days	---	---	---	---	---	---	---	---	---	---
Median days	---	---	---	---	---	---	---	---	---	---
Kilometers/d	---	---	---	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	1	4	10	0	0	1	5	6
Mean days	---	---	8.8	145.4	17.3	---	---	9.1	139.7	15.5
Median days	---	---	8.8	139.6	12.0	---	---	9.1	135.3	8.1
Kilometers/d	---	---	17.1	1.1	12.5	---	---	16.8	1.1	18.9

Table 4. Continued.

Year	Hood Park to Ice Harbor Dam 12km					Ice Harbor to L. Monumental Dam 51 km				
Release season:	Summer	Summer \fall	Fall	Wintered over	Spring	Summer	Summer /fall	Fall	Wintered over	Spring
1993										
Summer release										
Number of fish	0	0	0	0	0	0	0	0	0	0
Mean days	---	---	---	---	---	---	---	---	---	---
Median days	---	---	---	---	---	---	---	---	---	---
Kilometers/d	---	---	---	---	---	---	---	---	---	---
Fall release										
Number of fish	0	0	1	2	3	0	0	0	1	4
Mean days	---	---	20.5	152.1	14.1	---	---	---	162.3	32.8
Median days	---	---	20.5	152.1	17.1	---	---	---	162.3	31.5
Kilometers/d	---	---	7.3	1.0	8.8	---	---	---	0.9	4.9
1994										
Fall release										
Number of fish	0	0	1	0	1	0	0	0	0	1
Mean days	---	---	55.6	---	59.8	---	---	---	---	41.5
Median days	---	---	55.6	---	59.8	---	---	---	---	41.5
Kilometers/d	---	---	2.7	---	2.5	---	---	---	---	3.7

Steelhead released in the fall that migrated through reservoirs in the fall had migration rates of 13.0 to 31.1 km/d, and those that migrated in the spring had rates of 45.2 to 59.1 km/d. Steelhead that passed Lower Granite Dam and were recorded in the Clearwater River in the fall had the slowest migration rate through the reservoirs (13.0 km/d, n=48), except those that passed the dam in fall and entered the Clearwater River in winter (January-March) had a migration rate of 0.5 km/d (n=26).

1993

In 1993, migration rates for adult steelhead migrating through reservoirs and free flowing reaches were similar to rates observed in 1991 and 1992, and similar trends continued (Table 4, Figure 6). Steelhead released in summer at John Day Dam that migrated through the Snake River reservoirs in summer had migration rates of 7.0 to 29.4 km/d, while those that delayed and migrated through the reservoirs in fall had migration rates of 30.5 to 38.2 km/d.

Steelhead released in the fall and migrated through the reservoirs in the fall had migration rates of 13.7 to 33.3 km/d while those that migrated in the spring had rates of 29.1 to 45.5 km/d. Steelhead that passed Lower Granite Dam and were recorded in the Clearwater River in the fall had the slowest migration rate through the reservoirs (13.7 km/d, n=48) except those that passed the dam in fall and entered the Clearwater River in the winter (January-March) had a migration rate of 0.6 km/d (n = 20).

1994

Steelhead were released only in the fall in 1994. Median migration rates through the three lower Snake River reservoirs for fish that passed the lower Snake River dams before 31 December ranged from 14.3 to 45.4 km/d (Table 4, Figure 6). Steelhead that passed the dams the following spring moved rapidly once they resumed their migration (16.1 to 41.9 km/d). Migration rates for steelhead that passed Lower Granite

Dam in the fall and entered the Clearwater River in the fall were much slower (14.3 km/d) than for steelhead that crossed the dam and entered the Clearwater River in the spring (41.9 km/d).

Migration Rates of Hatchery Versus Wild Steelhead

Passage times for hatchery and wild steelhead with transmitters in each lower Snake River Reservoir were similar with the exception of the Lower Granite Dam to Clearwater River reach where hatchery and wild steelhead had median passage times of 11.15 d and 4.46 d, respectively (Table 5). Slower median passage times for hatchery steelhead in this reach could be related to the high number of Dworshak and Kooskia National Fish Hatchery steelhead that wintered over in the Lower Granite Reservoir. Median passage times for the reach from Lower Granite Dam to the Clearwater River receiver were also longer than those of any other reservoir including the Lower Granite Dam to Snake River receiver reach. Most of the steelhead that wintered over between Lower Granite Dam and the Clearwater and Snake River receiver sites eventually entered the Clearwater River in the spring and did not influence the Lower Granite to Snake River receiver site passage times.

Time to Migrate from Ice Harbor to Lower Granite Dams

In this section, we report the time to pass from the Ice Harbor Dam fishway exits to the Lower Granite Dam fishway exit. We examined four field seasons of data (summer 1991 through spring 1995), and used pooled data to compare median passage times between steelhead of hatchery and wild (unclipped) origins. All steelhead recorded at the two dams are included in the analysis, including those released in summer or fall that migrated between the two dams in the same season, and those that passed Ice Harbor Dam in summer or fall and then passed Lower Granite Dam the following spring.

In 1991, median passage time was a little more than 14 d for the 82 steelhead with good records at both sites. Median passage times decreased in each succeeding year to a low of about 7 d in 1994 (Figure 7). We do not have an explanation for the gradual decrease in passage time. Flows are usually not a source of variation during the period of steelhead migration.

Table 5. Number of hatchery and wild (those lacking an adipose fin clip were assumed to be of wild origin) steelhead with transmitters that passed through reservoirs in the Lower snake river in 1991-1995 with mean and median passage times (d). Confidence intervals are for median values.

	Hatchery				Wild			
	n	Mean	Median	95% CI	n	Mean	Median	95% CI
Ice Harbor to Lower Monumental Dam	618	2.91	1.35	1.29 - 1.42	179	4.05	1.61	1.44 - 1.87
Lower Monumental to Little Goose Dam	657	3.07	1.59	1.49 - 1.66	294	3.48	1.36	1.25 - 1.50
Little Goose to Lower Granite Dam	514	4.52	1.80	1.70 - 1.90	199	4.31	1.76	1.65 - 1.98
Lower Granite Dam to Snake R. receiver	330	6.18	2.86	2.61 - 3.17	148	8.21	3.16	2.63 - 3.91
Lower Granite Dam to Clearwater R. reciev.	246	38.91	11.15	5.82 - 19.80	83	28.78	4.46	2.66 - 6.52

Temperatures can be a factor, but most of the steelhead in this analysis passed between the two dams during the fall when temperatures do not impede migration. Trap operation at Ice Harbor Dam would not be a factor because the trap was downstream from the fishway exit. Operation of the adult trap at Lower Granite can add a day to the passage time for steelhead with transmitters because they are all diverted into the trap, but that delay should have been relatively constant for the four years. The median passage time for all steelhead during the four fish-years (1991-1995) was 8.4 d.

Pooled (1991-1995) median passage times for hatchery and wild steelhead were 8.0 d and 10.1 d. The relative frequency distributions of passage times for hatchery and wild steelhead are similar, but a higher percentage of wild steelhead had passage times longer than 14 d (Figure 8). For example, 79% of hatchery steelhead passed from the fishway exits at Ice Harbor Dam to the fishway exit at Lower Granite Dam within two weeks, compared to 66% for wild steelhead.

Migrations Rates Through Free-Flowing Rivers

Steelhead migration rates in free-flowing (unimpounded) reaches of rivers upstream from the lower Snake River reservoirs were affected by steelhead that wintered over in those reaches. Steelhead with transmitters that passed all four lower Snake River dams in the summer and fall wintered over in the upper end of Lower Granite Reservoir, the lower Clearwater River, the Snake River upstream from the reservoir, in the lower Grande Ronde River, and in the Salmon River and its major tributaries downstream from Salmon, Idaho. Migration rates are based on median migration times and the distance through each reach.

1991

Migration times and rates for steelhead with transmitters in the free-flowing reaches of the Snake and Salmon rivers were dependent on the stock of steelhead involved and their destination. Steelhead tagged in summer that migrated through the free-flowing reaches before 31 December migrated at faster rates than steelhead released in fall. Steelhead that migrated through the free-flowing reaches in spring had the highest migration rates when they resumed their migrations to spawning areas or hatcheries.

Six steelhead released with transmitters in 1991 migrated through the Snake River from the Snake River receiver site near Asotin into the Grande Ronde River (34 rkm) before 31 December. The one steelhead that migrated through the reach in the summer did so at a rate of 27.7km/d. The four steelhead that were released and migrated through the reach in the fall migrated at a rate of 1.7 km/d. The steelhead that migrated through the reach the following spring did so at a rate of 60 km/d, an indication of how fast the steelhead can migrate. Two steelhead that entered the reach in the fall but did not enter the Grande Ronde River until later in the winter had a migration rate of 0.2 km/d (Table 4, Figure 6).

Thirty-six steelhead with transmitters migrated the 205 rkm from the Asotin site to the Riggins site on the lower Salmon River before the end of 1991. Five of the steelhead were released in summer and migrated through the Asotin-to-Riggins reach in the fall at a median rate of 18.9 km/d. Twenty-four steelhead were released in the fall and migrated through the reach in the fall at a median rate of 14.5 km/d. The seven steelhead that entered the reach in fall, but delayed their migration and passed the Riggins site during the winter, migrated at a 1.8 km/d rate.

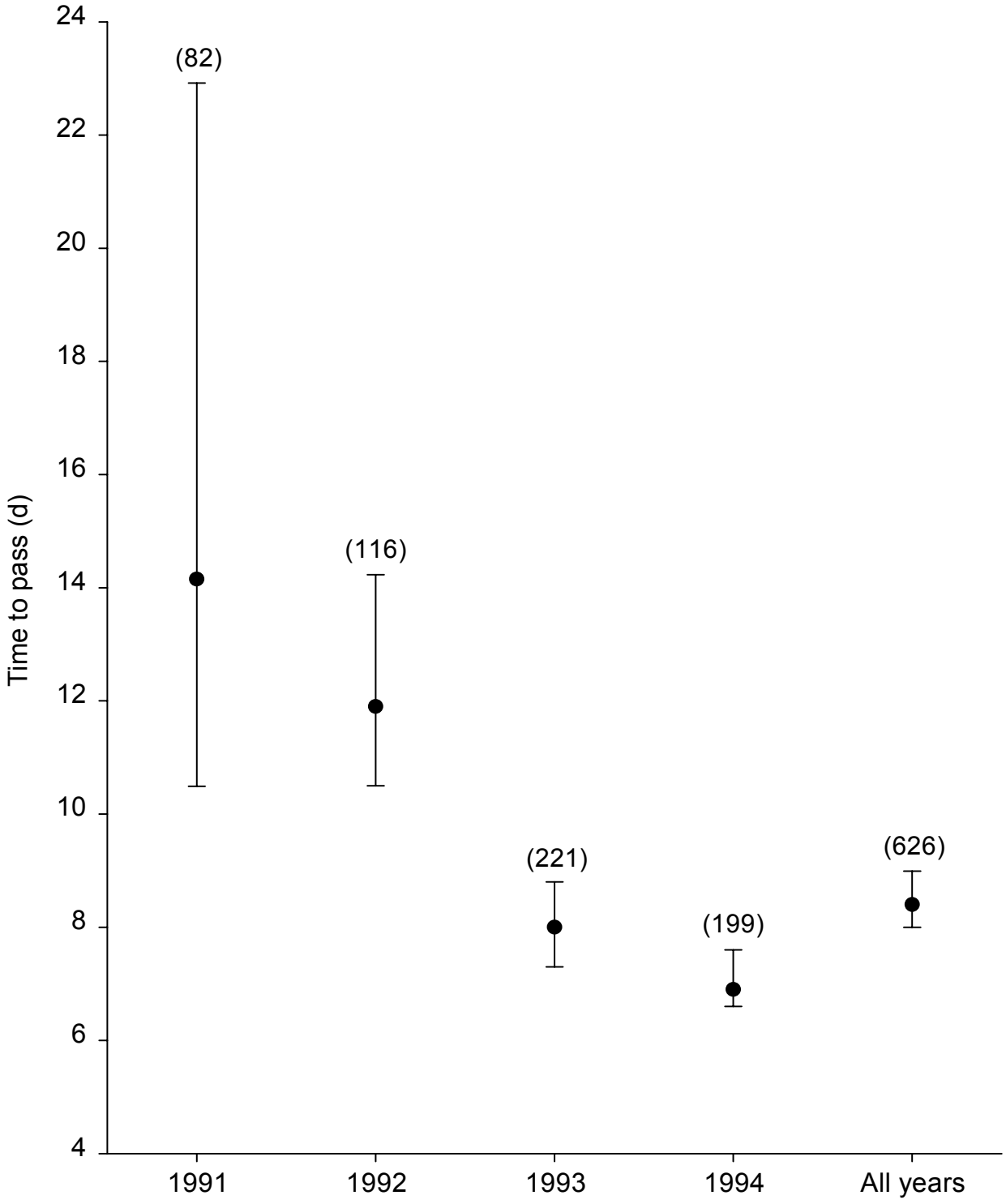

Figure 7. Median passage time for steelhead with transmitters from the Ice Harbor Dam fishway exit to the fishway exit at Lower Granite Dam in 1991-1995 and for all steelhead combined, including steelhead that migrated part way in fall and the remainder the next spring. Numbers in parentheses are sample size.

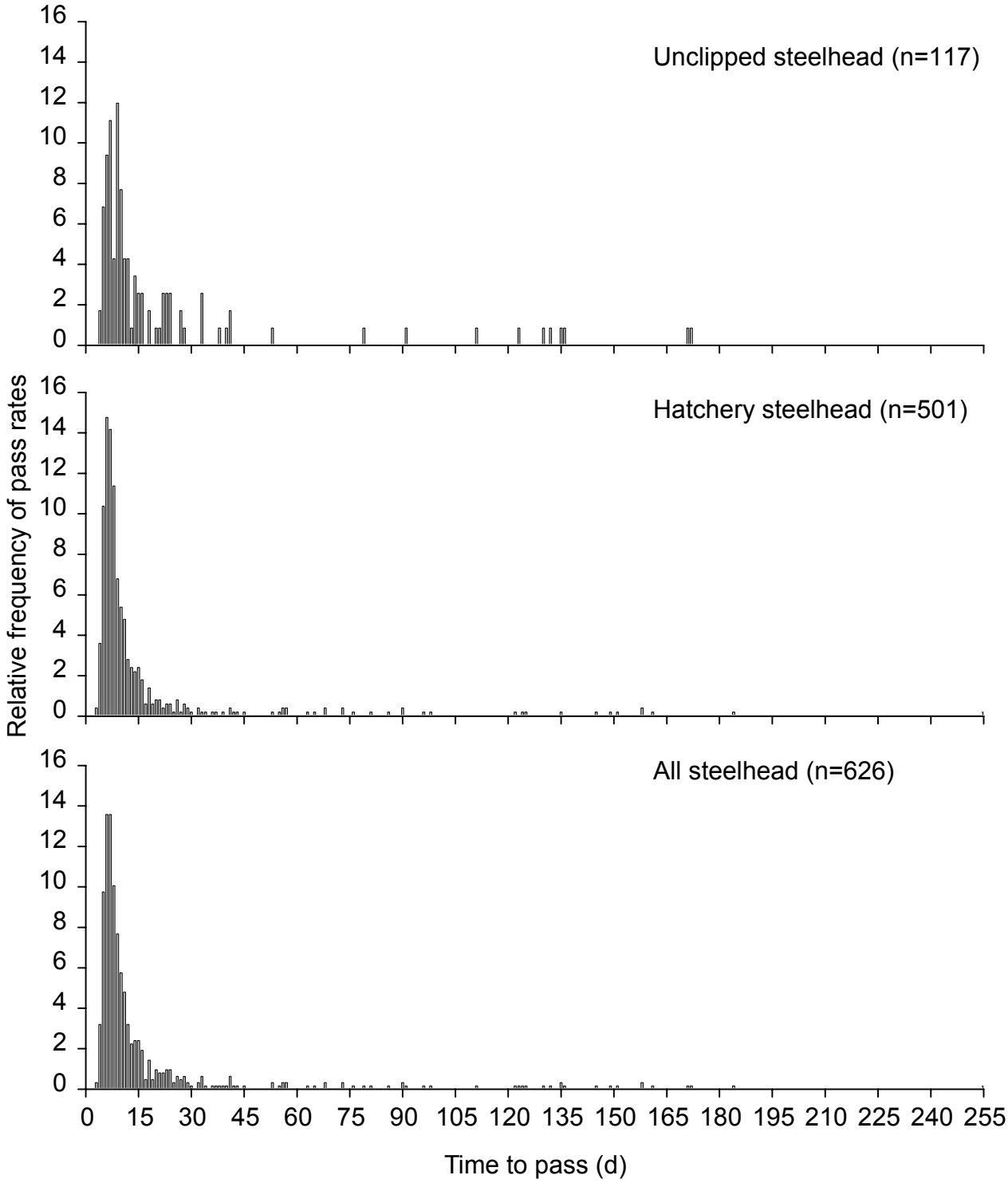

Figure 8. Relative frequency distribution of passage times for hatchery and wild steelhead, and all steelhead with transmitters from the fishway exit at Ice Harbor Dam to the fishway exit at Lower Granite Dam for steelhead released in 1991-1994 combined.

The one steelhead released in fall that migrated from Asotin to Riggins in the spring traveled at a 40.1 km/d rate.

Five steelhead with transmitters migrated the 132 rkm from the Riggins site to the site on the South Fork Salmon River near the mouth of the Secesh River (Table 4). All five were released in the fall, two passed Riggins in the fall but did not pass the South Fork site until winter (0.8 km/d) and three passed Riggins and the South Fork sites in the spring (4.8 km/d).

Twenty-one steelhead with transmitters migrated the 181 rkm from the Riggins site to the receiver site at the mouth of the Middle Fork Salmon River. Four of the steelhead were released in summer and migrated through that reach of the Salmon River in fall at a median rate of 11.1 km/d (Table 4). Two steelhead released in the fall migrated through the reach in the fall at a median rate of 8.0 km/d. Fourteen steelhead released in the fall migrated past the Riggins site in the fall and the Middle Fork site during the winter, these steelhead had a migration rate of 1.4 km/d. The one steelhead that migrated through the reach in the spring did so at a rate of 11.3 km/d.

Three steelhead with transmitters released in the fall migrated the 248 rkm from the Riggins to the Upper Salmon River sites at the mouth of the North Fork Salmon River during the fall and winter. All three steelhead passed the Riggins site in the fall and passed the upper Salmon River site in late winter with a rate of 1.6 km/d (Table 4). Eight steelhead that wintered over between the Middle Fork and Riggins sites migrated through the Middle Fork to upper Salmon reach in the spring at a rate of 8.8 km/d.

None of the steelhead with transmitters migrated upstream in the Clearwater River as far as the South Fork Clearwater, Lochsa or Selway rivers in the fall of 1991. Three steelhead passed the lower Clearwater River site in the fall, wintered over and were recorded passing receivers near the mouths of the South Fork and Lochsa rivers after 31 December with migration rates of 0.8 and 1.2 km/d. Four steelhead migrated from the lower Clearwater River receiver site and migrated passed the sites on the South Fork, Lochsa, and Selway rivers in the spring with migration rates of 5.8 to 29.7 km/d (Table 4).

1992

Migration rates of steelhead in free-flowing reaches in 1992 were similar to 1991 with the same general pattern of summer released steelhead migrating faster than those released in fall, and steelhead that resumed their migration in the spring moving at the fastest rates (Table 4, Figure 6).

Twenty-two steelhead with transmitters migrated through the Snake River from the Asotin site into the Grande Ronde River in 1992. Two were released in the summer and one passed through the reach in fall (24.0 km/d) and the other in the spring (7.7 km/d, Table 4). Of the 20 steelhead released in the fall that migrated through the Asotin-Grande Ronde reach, 9 migrated through the reach in the fall at a median migration rate of 9.0 km/d, 10 passed the Asotin site in the fall but did not enter the Grande Ronde River until spring (0.3 km/d), and one fish migrated through the reach in the spring at a rate of 45.0 km/d (Table 4).

Sixty-eight steelhead with transmitters migrated from the Asotin site to the Riggins site on the Salmon River. Ten were released in summer and 8 of those migrated through the Asotin to Riggins reach in fall at a median rate of 26.2 km/d, one steelhead wintered over in the reach and completed passage the next spring at a rate of 1.4 km/d and one steelhead migrated through the reach in the spring at a rate of 30.1 km/d (Table 4). The other 58 steelhead were released in the fall and 38 migrated through the reach in the fall at a median rate of 14.1 km/d, 16 steelhead wintered over in the reach and completed passage in the spring

at a rate of 1.4 km/d and 4 steelhead migrated through the reach in the spring at a rate of 18.1 km/d.

Five steelhead with transmitters that were released in fall migrated through the reach between the Riggins site and the South Fork Salmon River site. One of the fish wintered over in the reach and passed the South Fork site in the spring (0.7 km/d), and the other four migrated through the reach in the spring at 6.2 km/d (Table 4).

Fifteen steelhead migrated from the Riggins site to the site at the mouth of the Middle Fork Salmon River in the 1992-93 migration year. Four of the steelhead were released in summer and three migrated through that reach of the Salmon River in the fall at a median rate of 18.4 km/d; one steelhead migrated through that reach in the spring at a 17.5 km/d rate (Table 4). The remaining 11 steelhead were released in fall; one migrated through the reach in the fall at a rate of 14.7 km/d, 3 steelhead wintered over in the reach and migrated at a rate of 1.0 km/d and 7 steelhead migrated through the reach the next spring at a rate of 18.1 km/d.

Fourteen steelhead migrated from Riggins to the site at the mouth of the North Fork Salmon River in 1992-1993. Four were released in summer and 3 of those migrated through the reach in fall (13.9 km/d) and one migrated through the reach in spring (20.3 km/d). Of the 10 steelhead released in fall, 6 wintered over in the reach and migrated at a rate of 1.5 km/d and 4 migrated in spring (22.1 km/d).

Two steelhead released with transmitters in the summer migrated from the Middle Fork site to the North Fork site in the fall at a rate of 9.0 km/d (Table 4).

Thirty-four steelhead released with transmitters in 1992 migrated upstream in the Clearwater River into the South Fork, Lochsa, and Selway rivers. All of the steelhead that entered the tributaries were released in fall; 2 entered the tributaries in the fall and 32 entered in the spring. Seven steelhead migrated into the South Fork Clearwater River. Three steelhead that wintered over in the reach and entered the South Fork in the spring had a median migration rate of 0.9 km/d and 4 that migrated through the entire reach in the spring had a migration rate of 7.9 km/d (Table 4). Fifteen steelhead migrated into the Lochsa River: one migrated in the fall (17.1 km/d), 4 wintered over in the Clearwater River and entered the Lochsa River in the spring (1.1 km/d) and 10 migrated through the entire reach in the spring (12.5 km/d). Twelve steelhead migrated from the lower Clearwater River into the Selway River with one fish doing so in the fall at a rate of 16.8 km/d, 5 wintered over between the two sites and entered the Selway River in the spring (1.1 km/d) and 6 migrated through the entire reach in the spring (18.9 km/d).

1993

In 1993, steelhead were trapped and outfitted with transmitters at John Day Dam. However, migration rates of steelhead in free-flowing reaches of the Snake River were similar to those in the two prior years with the same general pattern of summer released steelhead migrating faster than those released in fall, and steelhead that migrated in the spring moving at the fastest rates (Table 4, Figure 6).

Twenty-one steelhead outfitted with transmitters in 1993 migrated through the Snake River from the receiver site near Asotin into the Grande Ronde River. Six of the steelhead were released in summer; one migrated past the Asotin site in the summer and entered the Grande Ronde River in fall with a migration rate through the reach of 3.7 km/d, 3 steelhead migrated through the reach in the fall (3.4 km/d), 1 steelhead wintered over in the reach and migrated into the Grande Ronde River in the spring (0.6 km/d), and one steelhead migrated through the reach in the spring (25.0 km/d). Of the 15 steelhead released in the

fall that entered the Grande Ronde River, 6 migrated through the Asotin-Grande Ronde reach in fall (1.7 km/d), 5 passed the Asotin site in the fall and entered the Grande Ronde River in the spring (0.4 km/d) and 4 migrated through the reach in the spring (25.7km/d) (Table 4).

Fifty steelhead migrated from the Asotin site to the Riggins site on the Salmon River during the 1993-1994 fish year. Nine of the steelhead were released in summer; 2 steelhead passed the Asotin site in the summer and passed the Riggins site in the fall with a median migration rate of 6.8 km/d, 6 migrated through the Asotin to Riggins reach in the fall (21.1 km/d) and 1 steelhead wintered over in the reach and passed the Riggins site in the spring (1.4 km/d) (Table 4). Forty-one of the 50 steelhead were released in the fall; 13 migrated through the reach in the fall (13.7 km/d), 26 steelhead wintered over in the reach and passed the Riggins site in the spring (1.5 km/d) and one steelhead migrated through the reach in the spring (18.4 km/d).

None of the steelhead outfitted with radio transmitters at John Day Dam in 1993 were recorded in the South Fork Salmon River.

Twenty-six steelhead released in the summer and fall of 1993 migrated from the Riggins site to the Middle Fork Salmon River site. Three of these fish were released in summer, wintered over in that reach and passed the Middle Fork site in the spring with a median rate of 1.1 km/d (Table 4). The remaining 22 steelhead were released in fall; 7 wintered over in the reach and had a median migration rate of 1.2 km/d, and 15 migrated through the reach in the spring (12.5 km/d).

Twenty-one steelhead migrated from Riggins to the North Fork site. Three steelhead were released in summer, wintered over in the reach and passed the North Fork site in the spring with a median migration rate of 1.4 km/d (Table 4). The remaining 18 were released in fall, of which 6 wintered over in the reach (1.6 km/d), and 12 migrated through the reach in the spring (12.2 km/d).

Twenty-three steelhead migrated through the Middle Fork to North Fork reach after they were released in 1993 at John Day Dam. Four of the fish were released with transmitters in the summer, with one fish passing the Middle Fork site in the fall and wintering over in the reach before passing the North Fork site in the spring with a migration rate of 0.8 km/d; the three remaining steelhead migrated through the reach in the spring at a rate of 5.0 km/d (Table 4). Nineteen steelhead released in the fall migrated through the reach the following spring with a median migration rate of 12.3 km/d.

Seventeen steelhead, all released in the fall of 1993 at John Day Dam, migrated upstream in the Clearwater River past the receiver sites on the South Fork, Lochsa, and Selway rivers. Six of the 17 steelhead migrated into the South Fork Clearwater River; one passed the lower Clearwater River site in the fall and then wintered over in that reach before entering the South Fork in the spring (0.8 km/d) and 5 migrated through the reach in the spring (4.0 km/d) (Table 4). Six steelhead entered the Lochsa River, 1 in the fall with a migration rate of 7.3 km/d, 2 after over wintering in the Clearwater River (1.0 km/d), and 3 in the spring (8.8 km/d) after spending the winter downstream from the lower Clearwater River site. Of the five steelhead that entered the Selway River, one did so in the spring after over wintering in the Clearwater River (0.9 km/d), and 4 migrated through the entire reach the next spring (4.9 km/d) after wintering over downstream from the lower Clearwater River site.

Table 6. Number of hatchery and wild (no adipose fin clip) steelhead that passed through free-flowing reaches of rivers upstream from Lower Granite Reservoir in 1991-1995 with mean and median passage times (d). Confidence intervals are for median values.

	Hatchery				Wild			
	n	Mean	Median	95% CI	n	Mean	Median	95% CI
Clearwater R. receiver to South Fork Clearwater R.	22	44.7	30.9	15.0 - 65.8	5	99.0	128.6	13.3 - 156.7
Clearwater R. Receiver to Lochsa R. receiver	6	33.2	26.6	15.1 - 59.8	19	57.1	21.4	11.7 - 131.1
Clearwater R. receiver to Selway R. receiver	1	41.5	41.5	-	18	52.1	33.0	9.1 - 62.8
Snake R. receiver to Grande Ronde R. receiver	46	47.5	29.5	10.4 - 65.6	20	41.7	9.7	2.7 - 59.7
Snake R. receiver to Salmon R. receiver	133	67.0	22.6	16.1 - 97.1	71	54.8	18.7	13.9 - 28.9
Salmon R. receiver to South Fork Salmon R.	0	-	-	-	10	59.9	26.1	9.4 - 165.3
Salmon R. receiver to Middle Fork Salmon R.	66	62.9	21.3	18.0 - 114.3	19	84.8	75.3	16.0 - 171.1
Salmon R. receiver to Upper Salmon R. receiver	48	75.6	30.4	23.2 - 140.8	8	125.2	150.6	11.9 - 187.1
Middle Fork Salmon R. To Upper Salmon R. receiver	51	11.3	6.0	4.9 - 7.2	4	13.9	10.1	3.6 - 31.9

1994

In the fall of 1994, steelhead were trapped at Ice Harbor Dam, outfitted with transmitters and released at Hood Park. All steelhead tagged had clipped adipose fins and were probably hatchery steelhead. Migration rates of steelhead in free-flowing reaches of the Snake River in 1994 were similar to those released in the fall in prior years, with steelhead that migrated in fall moving slower than those that migrated in the spring (Table 4, Figure 6).

Eighteen steelhead with transmitters migrated through the Snake River from the receiver site near Asotin into the Grande Ronde River; 8 in the fall with a median rate of 4.2 km/d, and 10 steelhead wintered over in that reach and entered the Grande Ronde River in the spring with a median migration rate of 0.5 km/d (Table 4).

Fifty of the steelhead released at Ice Harbor Dam in 1994 migrated from the Asotin site to the Riggins site on the lower Salmon River. Sixteen of the steelhead migrated through the reach in the fall and had a median migration rate of 17.5 km/d (Table 4). Thirty-one steelhead wintered over in the Asotin-to-Riggins reach and passed the Riggins site in the spring with a migration rate of 1.7 km/d, 3 steelhead wintered over downstream from Asotin and migrated through the reach in the spring (28.0 km/d).

None of the steelhead outfitted with transmitters in 1994 were recorded at the receiver site on the South Fork Salmon River.

Twenty-four steelhead migrated from the Riggins site to the Middle Fork Salmon River site. One migrated through the reach in the fall at a rate of 4.4 km/d, 8 wintered over in the reach and passed the Middle Fork site in the spring with a median migration rate of 1.3 km/d and the remaining 15 migrated through the reach in the spring (9.1 km/d) (Table 4).

Nineteen steelhead migrated from Riggins to the North Fork site. Eight wintered over in the reach and passed the North Fork site in the spring with a median migration rate of 1.7 km/d and 11 migrated through the reach in the spring (10.4 km/d) (Table 4).

Twenty steelhead with transmitters migrated through the Middle Fork to North Fork reach. One passed the Middle Fork site in the fall, wintered over in the reach and passed the North Fork site in the spring with a migration rate of 0.7 km/d. The other 19 migrated through the reach in the spring at a median rate of 10.1 km/d (Table 4).

Fifteen steelhead released with transmitters in 1994 migrated up the Clearwater River and into the South Fork Clearwater, Lochsa, and Selway rivers. Of the 12 steelhead that entered the South Fork, 6 wintered over between the lower Clearwater River site and the South Fork and had a migration rate of 1.3 km/d, and 6 migrated through the lower Clearwater River-South Fork reach in spring at a rate of 4.3 km/d (Table 4). Two fish migrated from the lower Clearwater River to the Lochsa River site: one wintered over in the reach and then entered the Lochsa River (2.7 km/d) and one migrated in the spring at a rate of 2.5 km/d. One steelhead migrated from the lower Clearwater River site into the Selway River in the spring and had a migration rate of 3.7 km/d through the reach.

Migration Rates of Hatchery Versus Wild Steelhead

Comparison of hatchery and wild steelhead passage times in free-flowing river reaches was difficult because many steelhead wintered over in the free-flowing rivers and usually had long passage times. We also had relatively small sample sizes for many reaches of river despite combining data for all four years (Table 6). For the reach with the largest sample sizes, Asotin to Riggins, median passage times were similar for the 133 hatchery (22.60 d) and 71 wild (18.65 d) steelhead when both groups were migrating to destinations upstream from the reach. In other reaches, median times to pass through the reach varied widely with no consistent trend for either hatchery or wild steelhead. Readers should refer to Table 4 for migration rates of steelhead that migrated through reaches during the same season, which removes the effect of the time spent overwintering. We did not find any consistent evidence that hatchery steelhead migrated faster or slower than wild steelhead. That finding should not be surprising, hatchery steelhead came from stocks of wild fish that spawned upstream from Lower Granite Dam and they would be expected to behave similarly with regard to timing of migration and overwintering location, except in cases where selection has taken place in the hatchery stocks.

Fallback of Steelhead at the Dams

Assessment of the percentage of steelhead that fall back, and their fallback rates (incorporates multiple fallbacks) at the Snake River dams was one objective of this study. The percentage of steelhead with transmitters that fell back at each of the lower Snake River dams ranged from 2.2% to 5.9% of all steelhead that passed the dams in all four years, with the exception of 1991 at Ice Harbor Dam (Table 7). At Ice Harbor Dam in 1991, up to 25% of the steelhead may have fallen back over the dam, but we suspect the percentage is lower for the following reasons. During this

first year of the study, SRX-400 scanning receivers were used to monitor all sites including tops of fishways. Because of the long scan time needed to monitor all the frequencies used, the reception range of each antenna needed to be quite large to have a high probability of recording all steelhead as they passed. At Ice Harbor Dam, the underwater antenna at the top of the south-shore fishway was strung through several pools downstream from the trap at the top of the fishway. Passage out the top of the south-shore fishway was impeded in 1991 because the trap was not lifted clear of the water when not in operation. Blocking gates below the trap were removed after trapping each day and the trap was left open, but we found later that the trap should be lifted clear of the water to avoid disruption of passage. We suspect that several steelhead with transmitters that ascended the fishway were recorded at the top-of-fishway antenna, encountered the trap, moved back down the ladder, and were not recorded as they exited the fishway into the tailrace. When those steelhead were then recorded at a tailrace site or reascended the fishways they were erroneously counted as fallbacks.

1991

In 1991, 68 of the 268 (25.4%) steelhead that passed Ice Harbor Dam following release at Hood Park were recorded in the tailrace or downstream from the dam after being recorded at the top of one of the fishways and were classed as fallbacks (Table 7). Twelve of the 68 steelhead that were classed as having fallen back did so twice, 1 fell back three times, and 1 fell back four times. Of the 68 steelhead that fell back, 54 (79.4%) reascended the fishways and passed the dam. Of the 12 steelhead that fell back twice, 9 reascended the dam. The 2 steelhead that fell back three and four times reascended the fishway and passed the dam. Twenty-nine of the 68 (43%) steelhead classed as fall backs, including the 6 steelhead that fell back twice, eventually were located either at hatcheries or spawning grounds. At least nine of the fallback steelhead were caught by anglers before they could complete their migration, thus 49% (29/59) of the remaining fallback steelhead completed their migrations according to our records. One steelhead that fell back was caught by an angler in the Walla Walla River and may have been destined for that system. Three steelhead, including one that fell back twice, were recaptured by anglers downstream from Ice Harbor Dam. Six fish were recaptured by anglers upstream from Ice Harbor Dam, but downstream from spawning grounds. Ten of the steelhead that fell back at Ice Harbor Dam, including two that fell back twice, also fell back at other dams.

Of the 263 steelhead released at Charbonneau Park (1.7 km upstream from Ice Harbor Dam) in 1991, 18 (6.8%) fell back over Ice Harbor Dam (one twice). Nine (50%) of these steelhead, including the fish that fell back twice, reascended Ice Harbor Dam, and six (33%) were recaptured or relocated at either spawning grounds or hatcheries. One was caught by an angler upstream from Ice Harbor Dam but downstream from spawning grounds.

Sixteen (3.8%) of the 420 steelhead known to have passed Lower Monumental Dam in 1991 fell back and were recorded downstream from the dam (Table 7). One of the 16 steelhead fell back twice. Of the 16 steelhead, 10 (63%), including the steelhead that fell back twice, reascended the dam. Seven of the 16 (44%) that fell back returned to hatcheries or spawning grounds. One was recaptured by an angler upstream from the dam, but downstream from spawning grounds. Five of the steelhead that fell back at Lower Monumental Dam fell back at other dams.

Thirteen (4.1%) of the 317 steelhead with transmitter known to have passed Little Goose Dam in 1991 fell back and were recorded downstream from the dam (Table 7).

Table 7. Numbers of adult steelhead that passed the four lower Snake River dams with transmitters, fell back over the dams, reascended after falling back, fell back at other dams, and were recorded in spawning grounds or hatcheries after they fell back.

Year Dam	Passed the dam	Fell back	Reascended	Fell back at other dams	Spawning grounds
1991					
Ice Harbor Dam	268	68	54	10	29
Lower Monumental Dam	420	16	10	5	7
Little Goose Dam	317	13	7	5	6
Lower Granite Dam	286	17	12	5	8
1992					
Ice Harbor Dam	228	7	3	5	1
Lower Monumental Dam	478	12	2	9	2
Little Goose Dam	398	18	6	10	7
Lower Granite Dam	352	19	8	7	10
1993					
Ice Harbor Dam	359	18	10	6	11
Lower Monumental Dam	337	9	5	5	4
Little Goose Dam	305	15	4	7	7
Lower Granite Dam	291	13	7	5	6
1994					
Ice Harbor Dam	368	9	6	4	4
Lower Monumental Dam	360	8	4	5	2
Little Goose Dam	347	10	5	4	5
Lower Granite Dam	331	9	6	3	5

Of the 13 steelhead, 7 (54%) reascended the dam and 6 (46%) migrated to spawning grounds or hatcheries. One steelhead was last located in the Tucannon River and was probably destined for that river. Two were caught by anglers downstream from Little Goose Dam.

At Lower Granite Dam in 1991, 17 (5.9%) of the 286 steelhead known to have passed the dam fell back and were recorded downstream from the dam (Table 7). Two steelhead fell back twice. Of the 17 steelhead, 12 (71%) reascended the dam (including the 2 that fell back twice). Eight (47%) of the steelhead that fell back, including the 2 that fell back twice, migrated to hatcheries or spawning grounds. Two steelhead were caught by anglers upstream from the dam but downstream from any likely spawning areas. Five of the steelhead that fell back at Lower Granite Dam, including one of the steelhead that fell back twice, fell back at other dams.

1992

The fall back rate observed at Ice Harbor Dam in 1992 was lower than in 1991, probably because we changed the antenna setup at the top of the fishway and operation of the trap (Table 7). In 1992, 228 of the steelhead released at Hood Park passed Ice Harbor Dam with transmitters and 7 (3.1%) of them fell back and were recorded downstream from the dam. Three of the 7 steelhead that fell back reascended the dam. One of the 3 steelhead that reascended was caught by an angler in the Walla Walla River and one was later located at a hatchery or potential spawning area.

Five of the steelhead that fell back at Ice Harbor also fell back at other dams.

Of the 377 steelhead released at Charbonneau Park in 1992, 16 (4.2%) fell back at Ice Harbor Dam, two of them twice. Eleven of these 16 (69%) steelhead reascended. One steelhead was relocated in the Umatilla River and may have been destined for that stream. Five steelhead (31%) were relocated at either hatcheries or potential spawning areas.

Twelve (2.5%) of the 478 steelhead with transmitters known to have passed Lower Monumental Dam in 1992 fell back and were recorded downstream from the dam (Table 7). Two of the 12 (17%) steelhead that fell back reascended and passed the dam a second time. Nine of the 12 steelhead that fell back at Lower Monumental Dam also fell back at other dams. Only two of the 12 (17%) steelhead that fell back were relocated at either hatcheries or potential spawning areas. One fish was relocated in the Walla Walla River and may have been destined for that stream.

At Little Goose Dam in 1992, 18 (4.5%) of the 398 steelhead with transmitters that passed the dam fell back and were recorded downstream from the dam (Table 7). Ten of the steelhead that fell back at Little Goose Dam also fell back at other dams. Six (33%) of the steelhead that fell back at Little Goose Dam reascended and passed the dam. Seven (39%) of the steelhead that fell back at Little Goose Dam were relocated either at hatcheries or potential spawning areas. One steelhead was caught by an angler downstream from the dam, two were relocated in the Tucannon River, and one was last located in the Snake River near Lyons Ferry Hatchery and may have been destined for that facility.

Nineteen (5.4%) of the 352 steelhead with transmitters that passed Lower Granite Dam in 1992 fell back and were located downstream from the dam (Table 7). One fish fell back twice. Eight of the 19 (42%) steelhead that fell back at Lower Granite Dam, including the steelhead that fell back twice, reascended the dam. Ten (53%) of the steelhead that fell back were relocated at either hatcheries or potential spawning areas. One steelhead was relocated in the Tucannon River. Seven of the steelhead that fell back at Lower Granite Dam also fell back at other dams.

1993

In 1993, 18 (5.0%) of the 359 steelhead known to have passed Ice Harbor Dam fell back (Table 7). One steelhead fell back twice. Ten (56%) of the steelhead that fell back at Ice Harbor Dam, including the steelhead that fell back twice, reascended the dam. Eleven (61%) of the steelhead that fell back were relocated either at hatcheries or potential spawning areas. Two steelhead were relocated in streams downstream from Ice Harbor Dam, one in Mill Creek (tributary of the Walla Walla River) and one in the Walla Walla River. Six of the 18 steelhead that fell back at Ice Harbor Dam also fell back at other dams.

Nine (2.7%) of the 337 steelhead with transmitters that passed Lower Monumental Dam in 1993 fell back (Table 7). Five of the 9 (56%) steelhead that fell back reascended the dam. Four (44%) of the steelhead that fell back eventually were located either at hatcheries or at potential spawning areas. One was relocated in Mill Creek, and two were recaptured upstream from Lower Monumental Dam but downstream from Little Goose Dam. Five of the nine steelhead that fell back at Lower Monumental Dam in 1993 also fell back at other dams.

Fifteen (4.9%) of the 305 steelhead with transmitters that passed Little Goose Dam in 1993 fell back (Table 7). Only four of the 15 (27%) reascended the dam. One steelhead was recaptured by an angler downstream from the dam, one was recaptured at Lyons Ferry Hatchery, one was last located in the Snake River near Lyons Ferry Hatchery and may have been destined for

that facility, and two were last located in streams downstream from Little Goose Dam (one in the Tucannon River and one in Mill Creek). Five of the 15 steelhead that fell back at Little Goose Dam also fell back at other dams.

At Lower Granite Dam in 1993, 13 (4.5%) of the 291 steelhead known to have passed the dam fell back (Table 7). Two steelhead fell back twice. Seven of the 13 (54%) steelhead, including one of the steelhead that fell back twice, reascended the dam. The second steelhead that fell back twice was caught by an angler downstream from Lower Granite Dam. Six of the 13 (46%) fallback steelhead were relocated either at hatcheries or at potential spawning areas. One steelhead was recaptured at Lyons Ferry Hatchery and one was last located in Mill Creek. Five of the 13 steelhead that fell back at Lower Granite Dam in 1993 also fell back at other dams.

1994

The percentage of steelhead with transmitters that fell back at each of the four lower Snake River dams in 1994 ranged from 2.2% at Lower Monumental Dam to 2.9% at Little Goose Dam. Nine (2.5%) of the 368 adult steelhead that passed Ice Harbor Dam with a transmitter fell back and were recorded at fixed sites or by mobile trackers downstream from Ice Harbor Dam (Table 7). Six of the 9 (66%) steelhead that fell back at Ice Harbor Dam reascended the dam. Four (44%) of the steelhead that reascended the dam were eventually located or recaptured at spawning grounds or hatcheries. One steelhead was caught by an angler soon after reascending Ice Harbor Dam. Of the nine steelhead that fell back at Ice Harbor Dam, four fell back at other dams.

At Lower Monumental Dam, eight (2.2%) of the 360 steelhead that had transmitters when they passed the dam fell back in 1994 (Table 7). Four of the 8 (50%) steelhead that fell back reascended the dam. Two of the 8 (25%) that reascended were eventually located near spawning grounds. Two steelhead were captured by anglers after falling back over the dam, one after it had reascended Lower Monumental Dam, the second after it had fallen back to the tailrace of Ice Harbor Dam, reascended Ice Harbor Dam and was migrating back up through Ice Harbor Reservoir. Five of the 8 steelhead that fell back at Lower Monumental Dam fell back at other Snake River dams.

Ten of the 347 steelhead (2.9%) that passed Little Goose Dam in 1994 fell back (Table 7). Five of the 10 (50%) steelhead that fell back at Little Goose Dam reascended the dam. One of the 10 steelhead that fell back at Little Goose Dam did so twice and reascended each time, ultimately entering the Clearwater River. One of the 10 steelhead that fell back at Little Goose Dam entered the Tucannon River downstream from Little Goose Dam. Five of the 10 (50%) steelhead that fell back over Little Goose Dam were eventually located either at spawning grounds or hatcheries. Of the 10 steelhead that fell back at Little Goose Dam, four fell back at other Snake River dams.

At Lower Granite Dam, 9 of 331 (2.7%) adult steelhead with transmitters fell back and were recorded by receivers or mobile trackers downstream from the dam (Table 7). Six of the 9 (66%) steelhead that fell back at Lower Granite Dam reascended the dam and 5 (56%) were eventually located either at spawning grounds or hatcheries. Three of the 9 steelhead with transmitters that fell back at Lower Granite Dam fell back over one or more of the other Snake River dams.

Timing of Migration Past Dams and into Tributaries

We monitored the timing of steelhead migrations past dams and into tributaries during each of the four years of study. Steelhead were tagged from July through

early November in all years except 1994 when tagging began in September. In this section we present information on the seasonal and diel times of passage at dams and at receiver sites at mouths of tributaries and key locations along rivers.

Seasonal Timing of Migration at Dams

In all four years most of the steelhead with transmitters moved upriver past the lower Snake River dams in the fall, a few passed the dams in summer and a few wintered over in the lower Snake River and passed Lower Granite Dam the following spring (Figures 9, 10, 11, and 12). Few steelhead released in summer migrated upstream as far as Lower Granite Dam in the summer.

Seasonal Timing of Migration at Tributary Sites

Most steelhead with transmitters that migrated past the receiver site on the Snake River near Asotin, WA passed the site in the fall of all years (Figures 13, 14, 15, 16), with a few steelhead arriving at the site during the winter and spring, primarily in March and April. Steelhead with transmitters recorded at the lower Clearwater River receiver site were recorded throughout the fall and spring with a few steelhead passing the receiver site in the winter. Many steelhead destined for the Clearwater River wintered over in Lower Granite Reservoir, the confluence of the Snake and Clearwater rivers, and the lower Clearwater River. Steelhead that entered the Grande Ronde River in 1991 and 1992 (Figures 13 and 14) did so exclusively during the fall and spring. In 1993 and 1994 (Figures 15 and 16) steelhead with transmitters entered the Grand Ronde River throughout the fall, winter, and spring. In the four years of the study, six steelhead with a transmitter were recorded entering the Imnaha River, all during the fall. Timing of movement past receiver sites on the Salmon River was consistent in all four years of the study (Figures 13, 14, 15, 16). Two peaks were observed at the receiver site located at Riggins on the lower Salmon River, one in the fall and one in the spring, with almost no movement during winter. A few steelhead passed the receiver site at the mouth of the Middle Fork of the Salmon River in the fall of each year but most passed that receiver in the spring. Almost all of the steelhead with transmitters passed the receiver site on the Salmon River at North Fork in the spring.

Seasonal Timing of Hatchery Versus Wild Steelhead

Most (90+%) of the hatchery and wild steelhead with transmitters passed the Lower Snake River dams in the summer and fall of the year they were tagged, but passage at tributary sites upstream from the dams by both groups was more related to distance upstream from Lower Granite Dam and overwintering sites (Table 8). Nearly all hatchery and wild steelhead passed the uppermost sites in the spring. With few exceptions, the proportions of steelhead that arrived at tributary sites in the summer/fall or spring did not differ much between hatchery or wild steelhead.

Seasonal Timing of Migration of Major Tributary Stocks at Dams

In this section we present information on the seasonal time of passage of steelhead by stock (fish that were last recorded in each of the major tributaries) and origin (hatchery versus wild) at Ice Harbor and Lower Granite dams. Time of passage of stocks was examined for each year (1991-1995) and for the 4 years of tagging combined to detect trends in timing at the two dams.

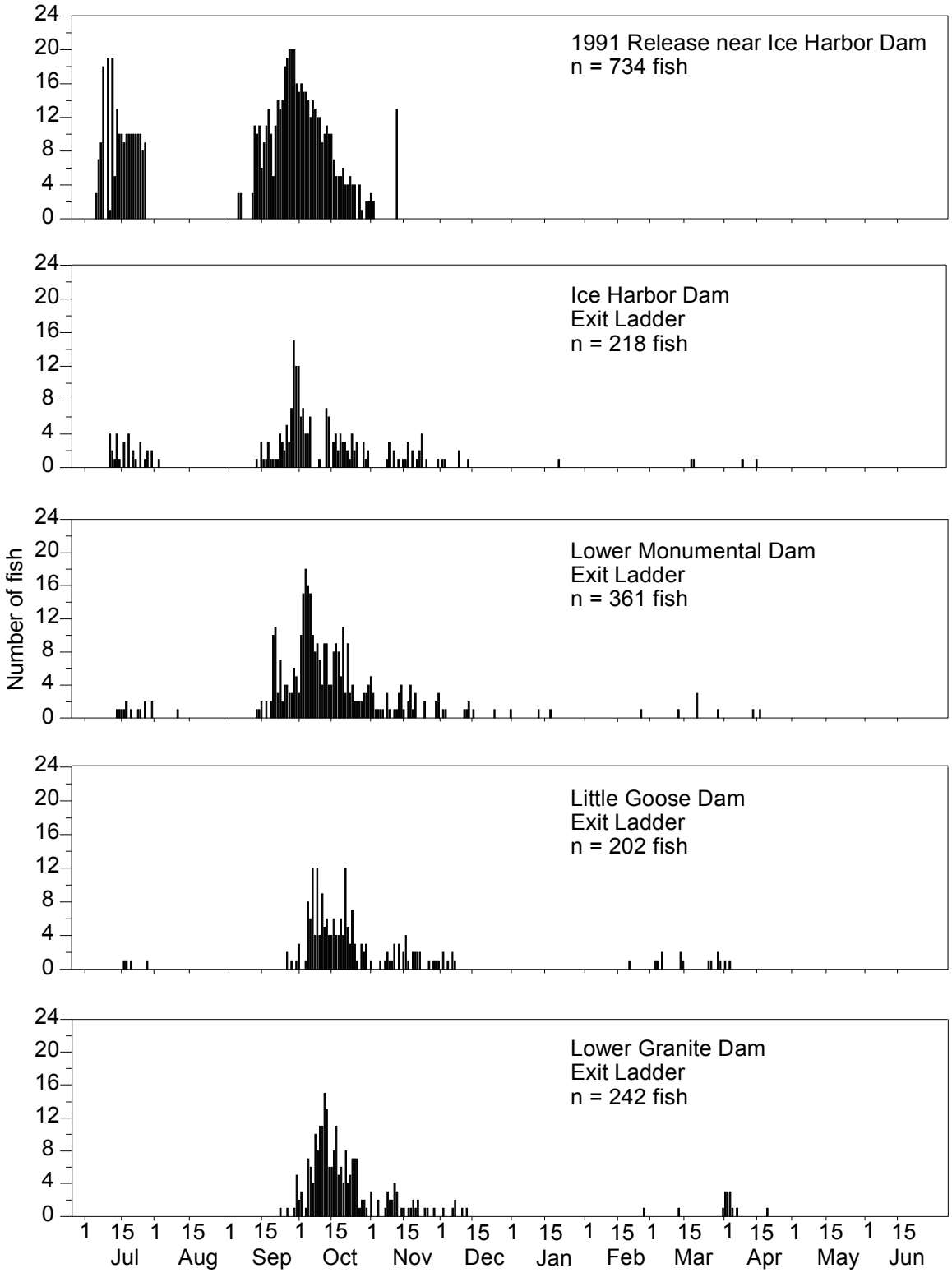

Figure 9. Dates of migration past dams in the lower Snake River of adult steelhead outfitted with radio transmitters and released near Ice Harbor Dam in 1991.

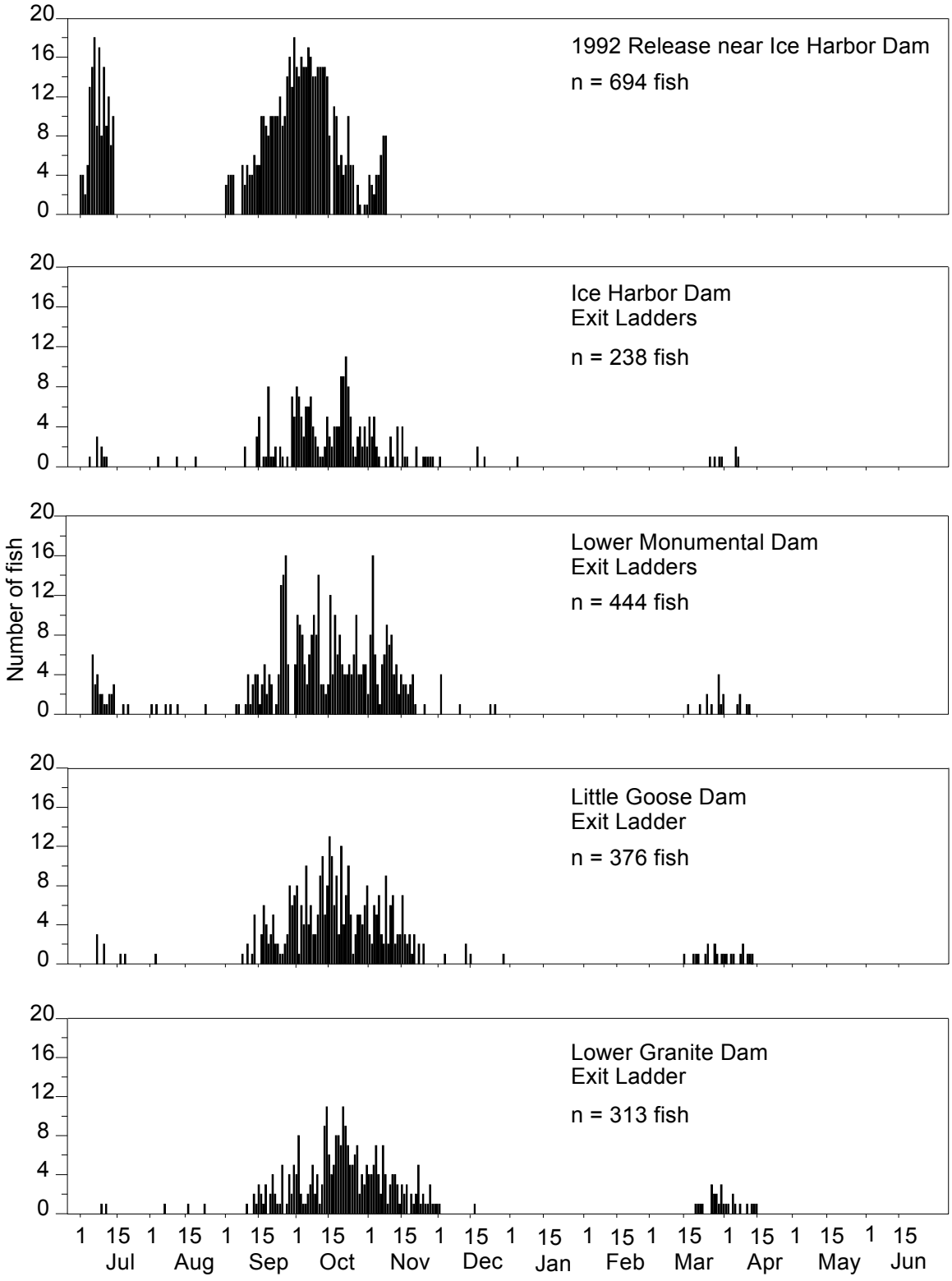

Figure 10. Dates of migration past dams in the lower Snake River of adult steelhead outfitted with radio transmitters and released near Ice Harbor Dam in 1992.

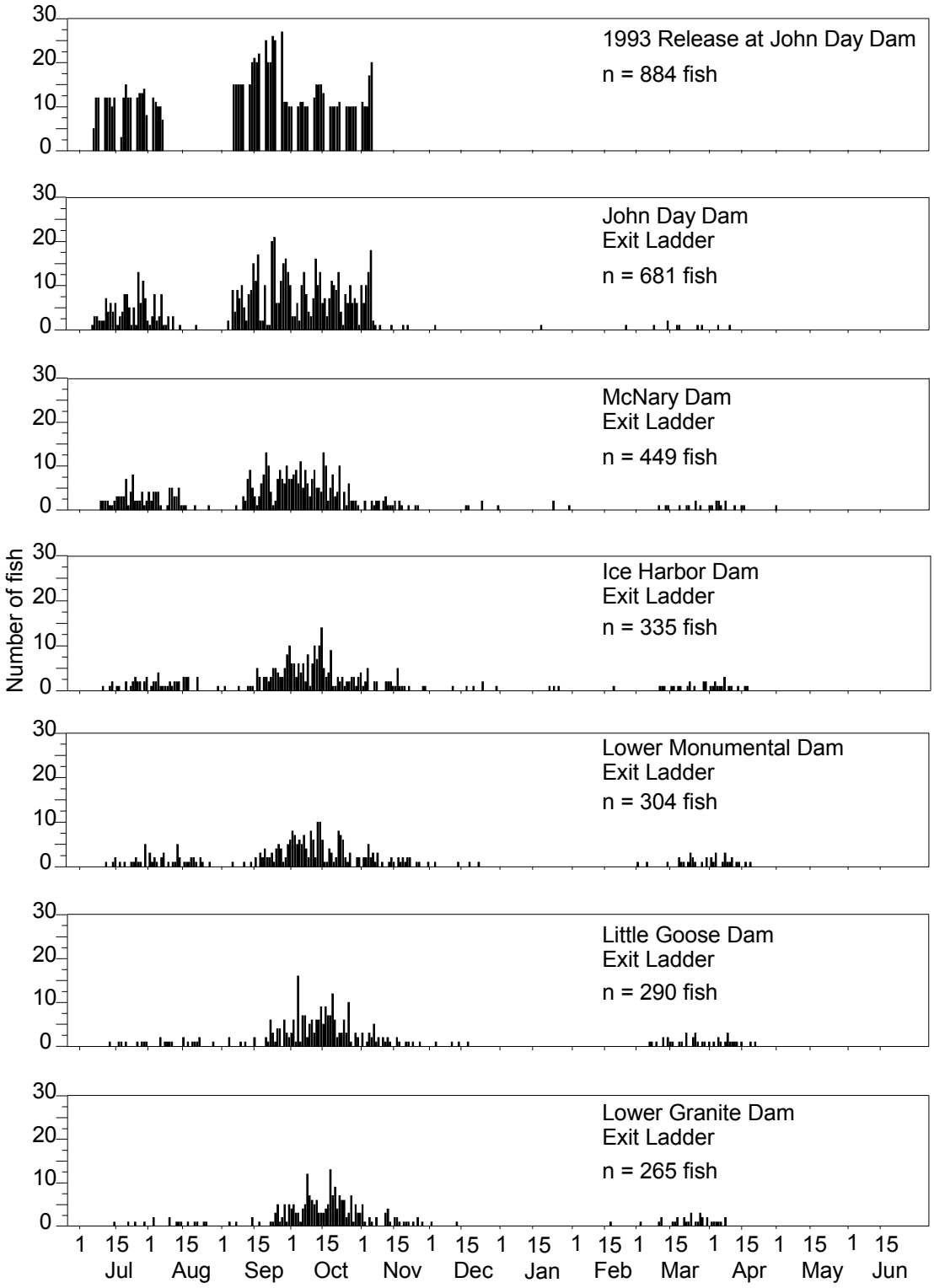

Figure 11. Dates of migration past dams in the lower Columbia and Snake River of adult steelhead outfitted with radio transmitters and released at John Day Dam in 1993.

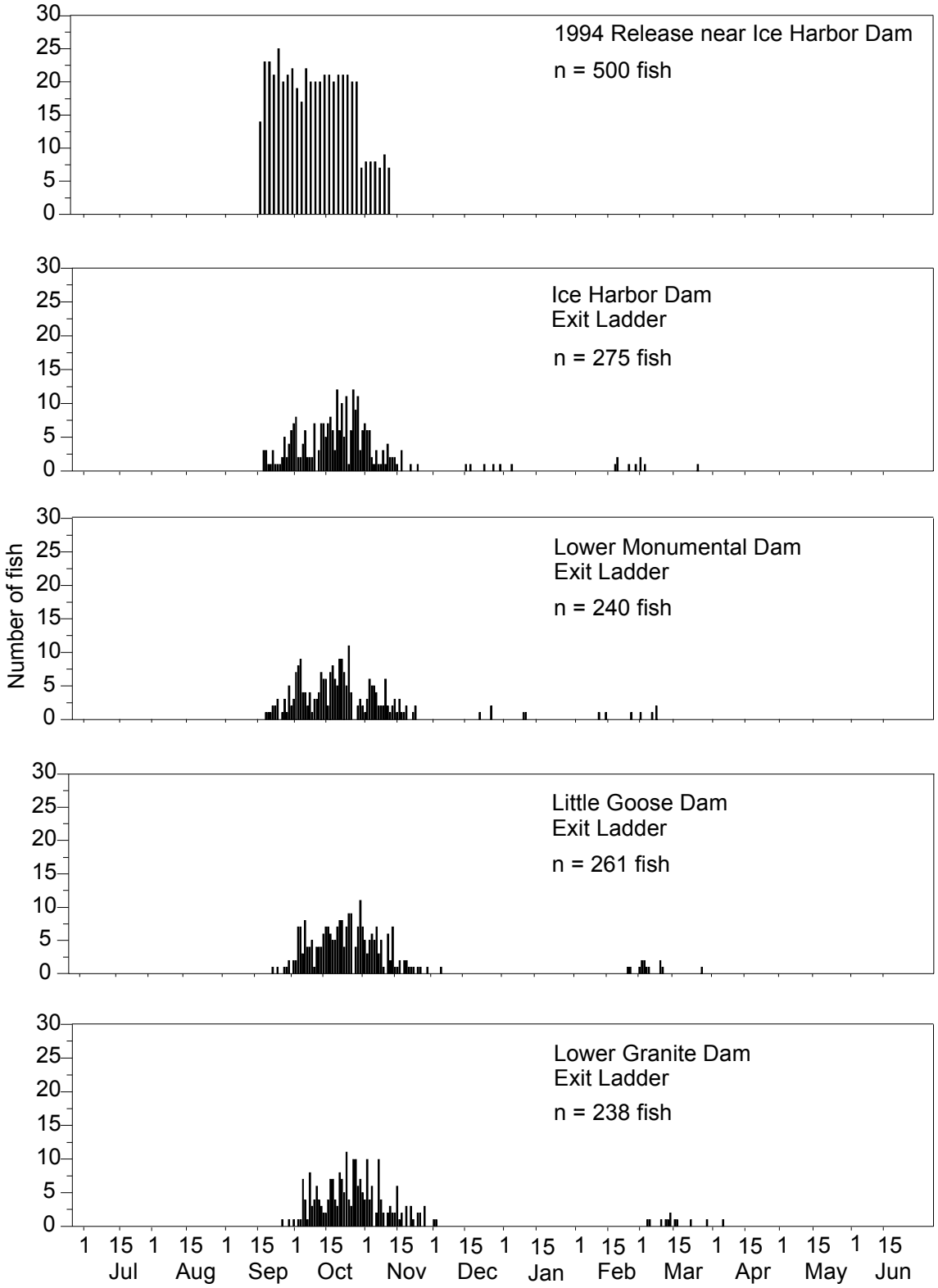

Figure 12. Dates of migration past dams in the lower Snake River of adult steelhead outfitted with radio transmitters and released near Ice Harbor Dam in 1994.

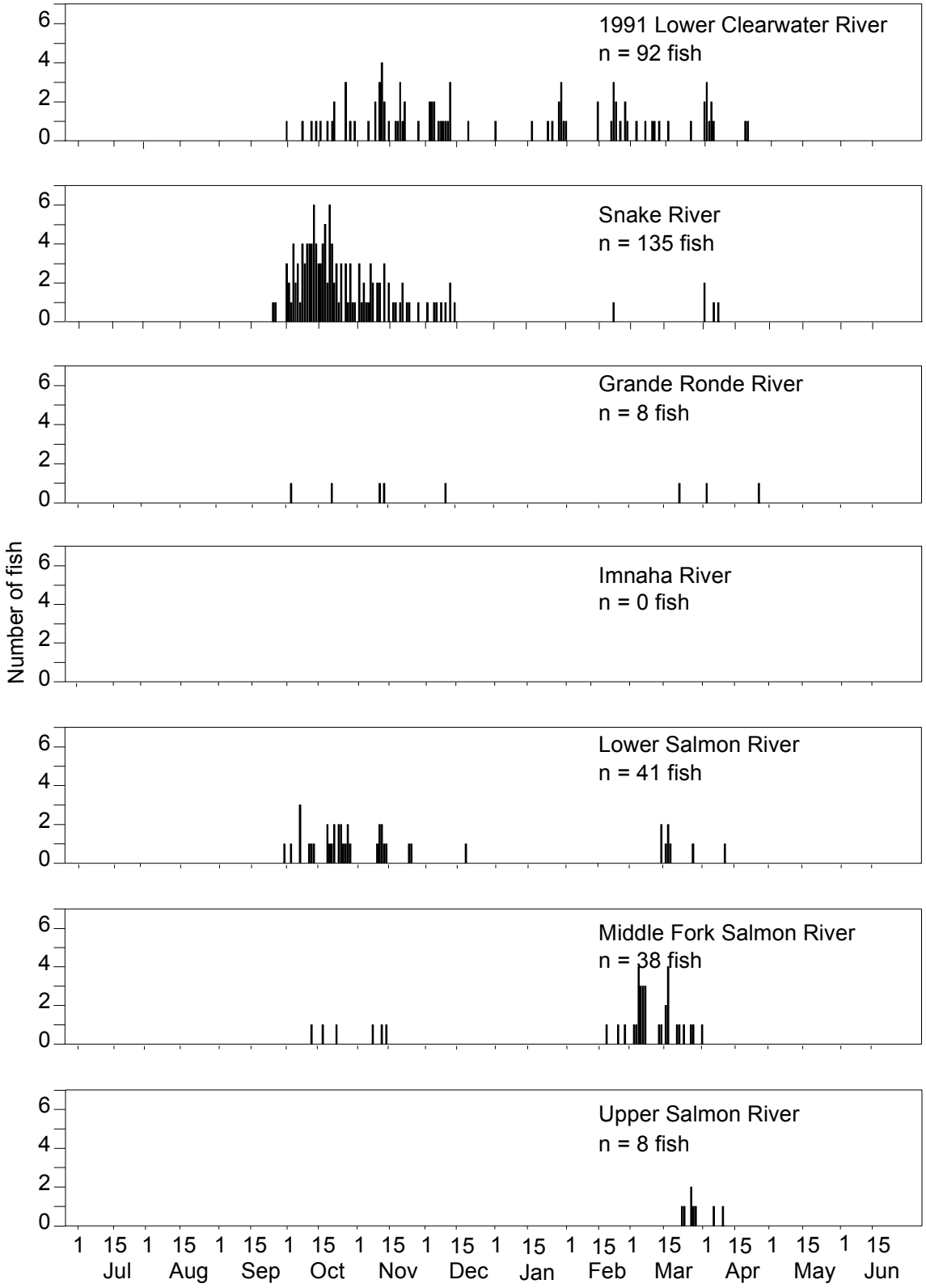

Figure 13. Dates of passage of adult steelhead outfitted with transmitters at tributary receiver sites for steelhead released in 1991.

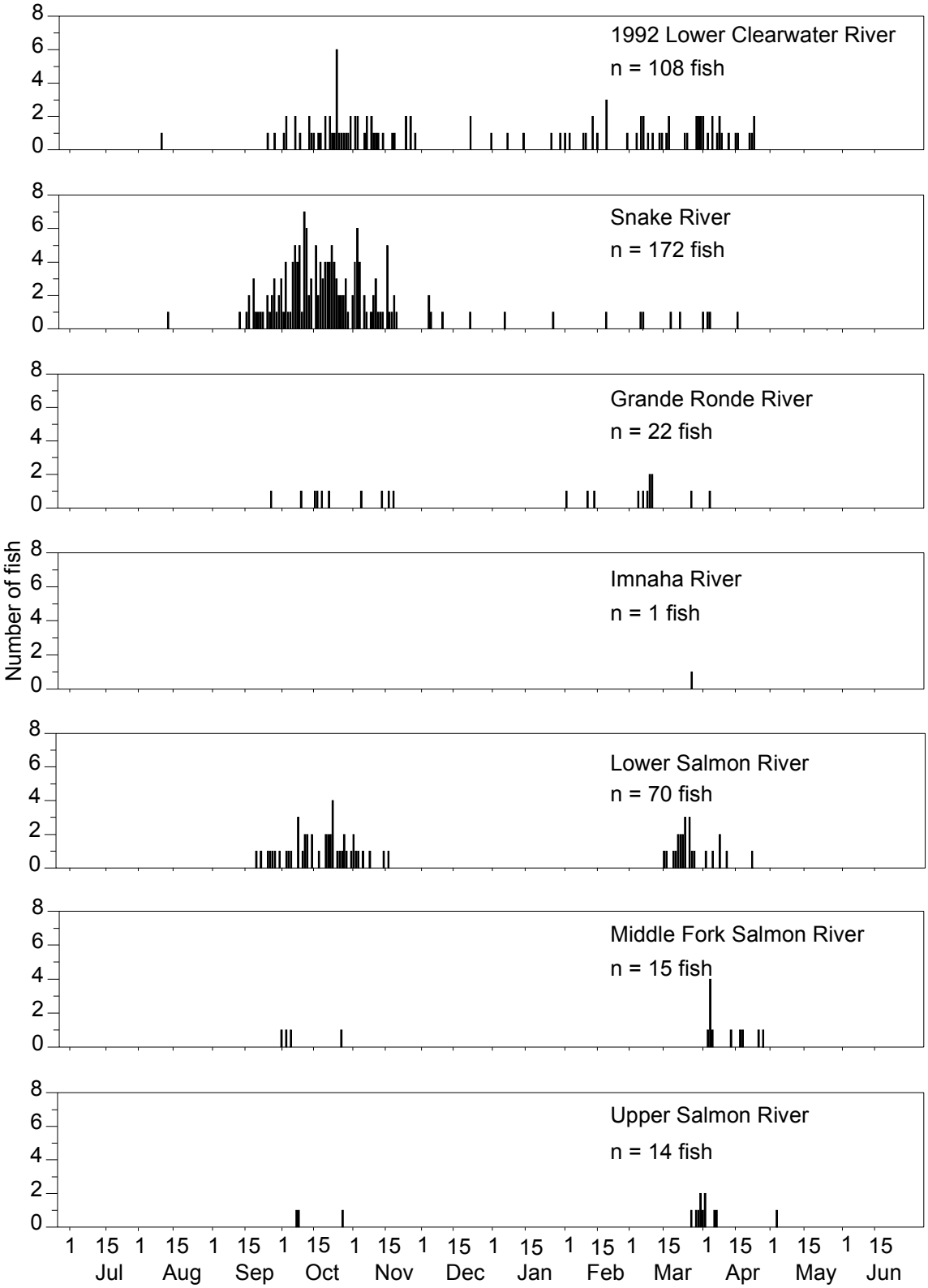

Figure 14. Dates of passage of adult steelhead outfitted with transmitters at tributary receiver sites for steelhead released in 1992.

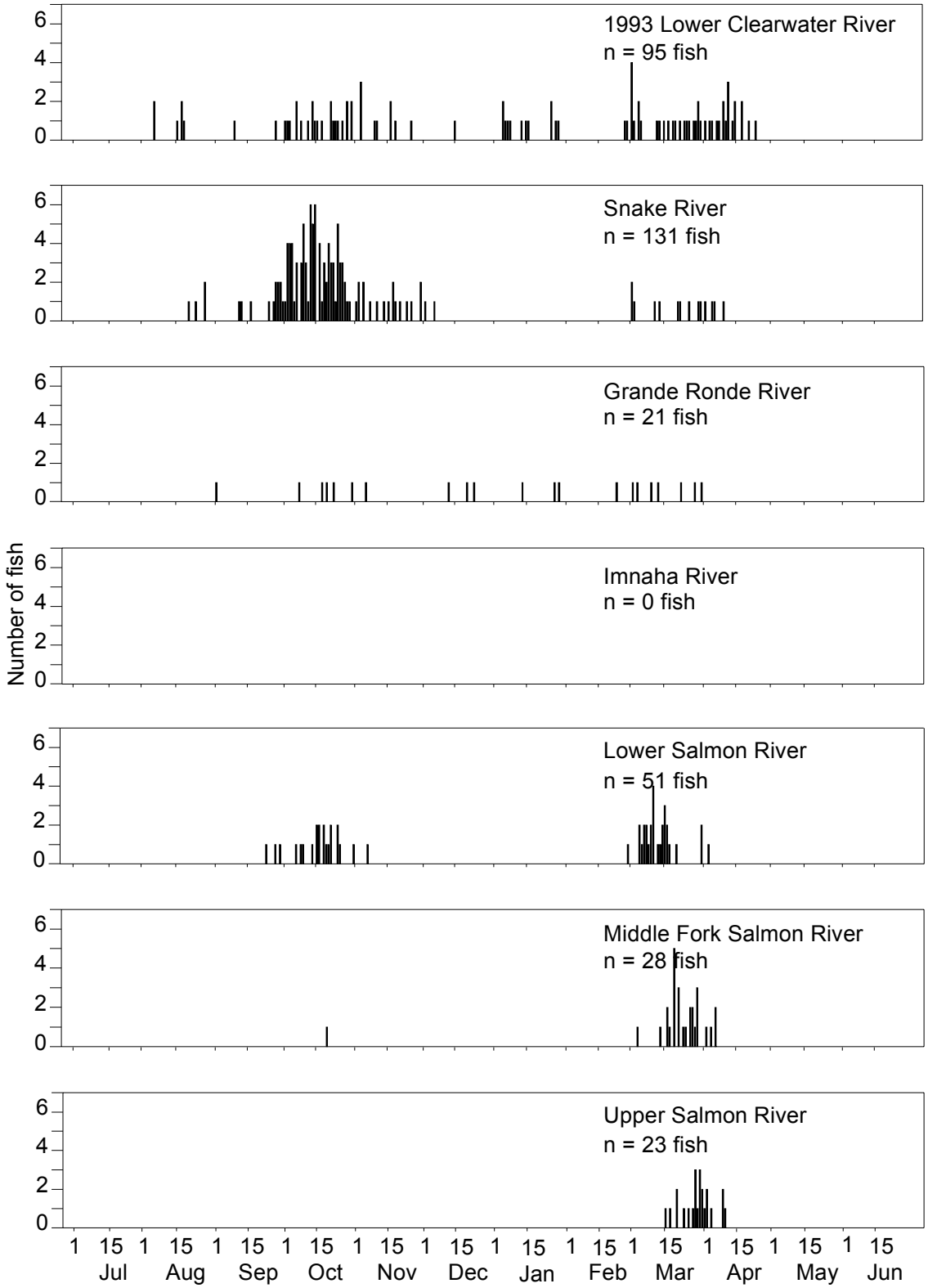

Figure 15. Dates of passage of adult steelhead outfitted with transmitters at tributary receiver sites for steelhead released in 1993.

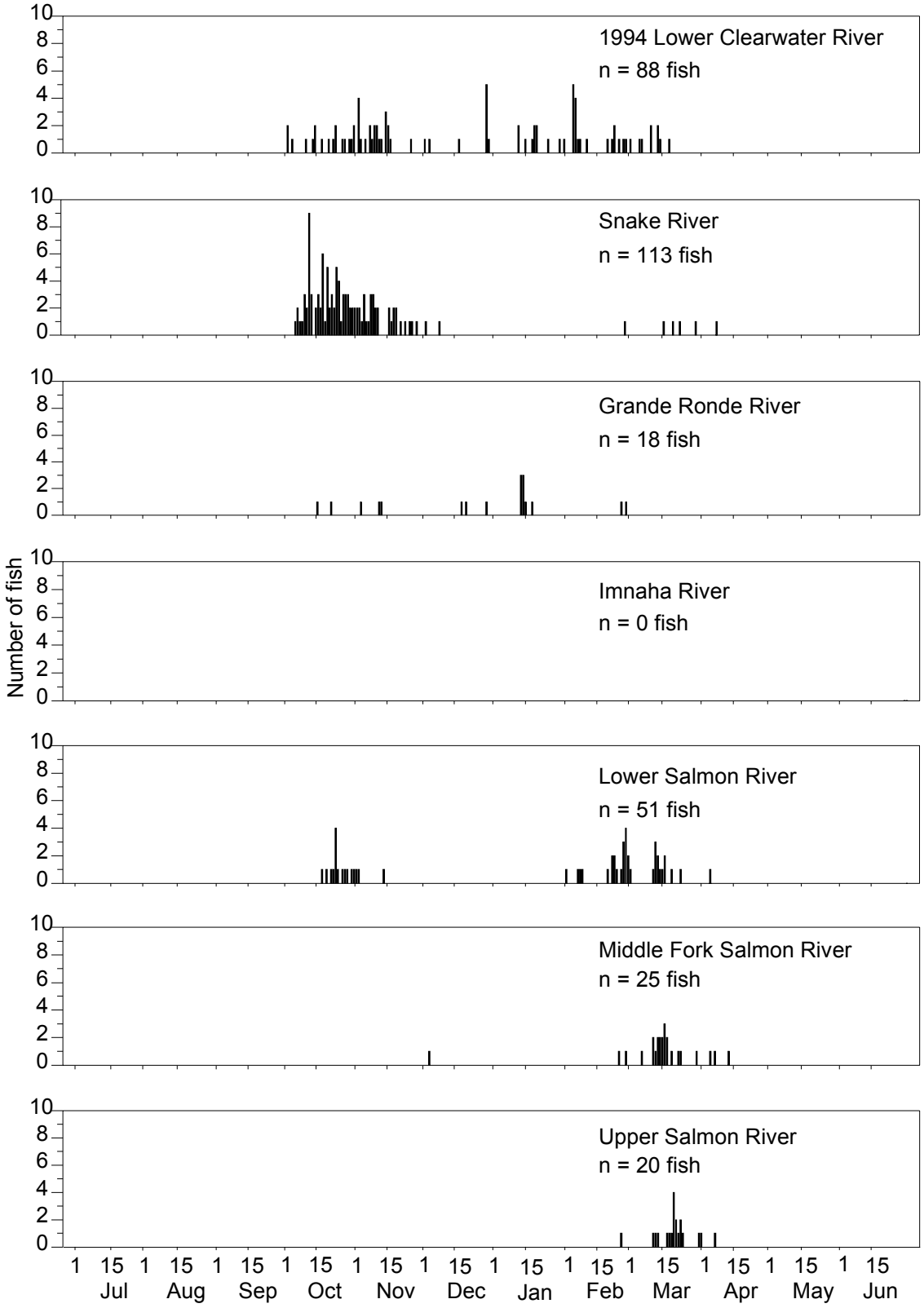

Figure 16. Dates of passage of adult steelhead outfitted with transmitters at tributary receiver sites for steelhead released in 1994

Four-year summary histograms were constructed for stocks with small sample sizes.

Because we tagged fish only in summer and fall at Ice Harbor Dam, steelhead with transmitters would be expected to pass the dam during summer and fall. This was generally the case, except that some of the fish released in summer downstream from Ice Harbor Dam delayed re-passing the dam until fall. Steelhead we tagged at John Day Dam in the summer and fall of 1993 passed Ice Harbor Dam exclusively in the summer and fall. Although we did not tag fish in the spring, we believe the steelhead we tagged were a representative sample of the stocks passing the two dams because a small percentage of each year's run of upriver steelhead pass John Day (2.3%) and Ice Harbor (3.8%) dams in the spring after wintering over downstream from those dams, based on fish count data (Corps of Engineers 1994).

As expected, due to date of tagging all steelhead last recorded in the Clearwater, Salmon, and Grande Ronde rivers arrived at Ice Harbor Dam prior to 31 December in each year that we tagged fish. At Lower Granite Dam, 95% of the steelhead from Salmon and Grande Ronde river stocks passed the dam prior to 31 December (Table 9). Only 2.7% of the steelhead last recorded in the Salmon River arrived at Lower Granite Dam in the spring after spending the winter downstream versus 18% of the steelhead destined for the Clearwater River. Steelhead from the Clearwater, Salmon, and Grande Ronde rivers arrived at Ice Harbor and Lower Granite dams at similar times in all four years (Figures 17, 18, 19, 20, 21, 22). There were too few steelhead that entered the other tributaries to make any generalizations.

For the four years combined, all steelhead last recorded in the Imnaha River, Snake River (upstream from the confluence of the Imnaha River to Hells Canyon Dam), Tucannon River, and Lyons Ferry Hatchery also arrived at Ice Harbor and Lower Granite dams prior to 31 December (Figures 23 and 24).

Table 8. Number and percent of hatchery and wild steelhead (no fin clips) with transmitters that arrived at receiver sites in the fall (before 31 Dec) and in the spring (after 31 Dec) at tailrace sites at dams and at tributary receiver sites, 1991-1995.

	Hatchery			Wild		
Site	n	% Fall	% Spring	n	% Fall	% Spring
Ice Harbor tailrace receiver	822	96.0	4.0	233	95.3	4.7
Lower Monumental tailrace receiver	910	95.2	4.8	340	94.1	5.9
Little Goose tailrace receiver	844	94.1	5.9	335	92.5	7.5
Lower Granite tailrace receiver	685	92.0	8.0	236	89.8	10.2
Lower Clearwater receiver	272	50.7	49.3	104	56.7	43.3
South Fork Clearwater R. receiver	23	-	100	5	-	100
Selway River receiver	1	-	100	18	5.6	94.4
Lochsa River receiver	6	33.3	66.6	20	5.0	95.0
Snake River receiver (Asotin, WA)	368	95.1	4.9	174	90.2	9.8
Grande Ronde River receiver	47	51.1	48.9	20	40.0	60.0
Imnaha River receiver	0	-	0	1	-	100
Lower Salmon River receiver	137	54.7	45.3	75	57.3	42.7
South Fork Salmon River receiver	2	-	100	15	-	100
Middle Fork Salmon River receiver	79	13.9	86.1	25	-	100
Upper Salmon River receiver	55	5.5	94.5	9	-	100

Table 9. Percent of steelhead with transmitters arriving at Ice Harbor (IH) and Lower Granite (GR) dams by stock [Clearwater River (CWR), Grande Ronde River (GRR), Imnaha River (IMR), Lyons Ferry Hatchery (LFH), Salmon River (SAL), Snake River (SNR), and Tucannon River (TUC)] and month, with mean percent of all steelhead that arrived at each dam for steelhead tracked during the summer 1991 through spring 1995 field seasons.

			Percent during											
Dam	Stock	n	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
IH	CWR	490	3.1	0.6	36.5	53.5	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRR	74	13.5	0.0	45.9	37.8	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	IMR	6	0.0	0.0	50.0	16.7	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LFH	14	57.1	0.0	35.7	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SAL	297	10.4	1.0	55.2	32.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SNR	13	23.1	7.7	46.2	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TUC	3	0.0	33.3	33.3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	mean	-	15.3	6.1	43.3	29.1	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR	CWR	475	0.2	0.4	4.0	50.5	24.6	2.3	0.0	0.4	9.7	7.8	0.0	0.0
	GRR	72	1.4	0.0	11.1	56.9	23.6	1.4	1.4	0.0	4.2	0.0	0.0	0.0
	IMR	6	0.0	0.0	16.7	33.3	33.3	0.0	0.0	0.0	16.7	0.0	0.0	0.0
	LFH	1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SAL	295	0.0	1.4	14.6	67.1	13.2	1.0	0.0	0.0	1.7	1.0	0.0	0.0
	SNR	13	0.0	0.0	7.7	76.9	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TUC	2	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
	mean	-	0.2	14.5	7.7	40.7	22.9	7.8	0.2	0.1	4.6	1.3	0.0	0.0

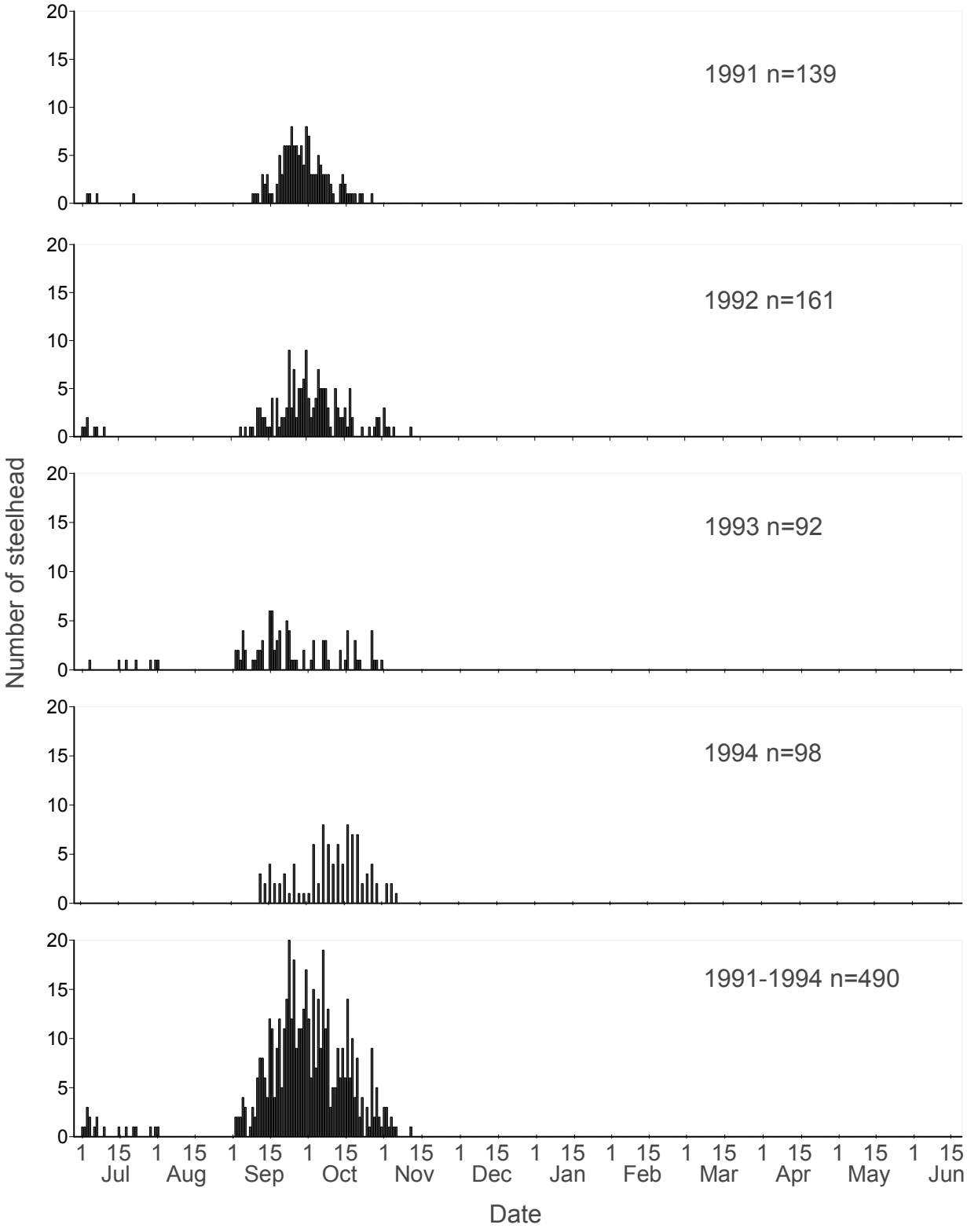

Figure 17. Frequency distribution of arrival dates at Ice Harbor Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Clearwater River.

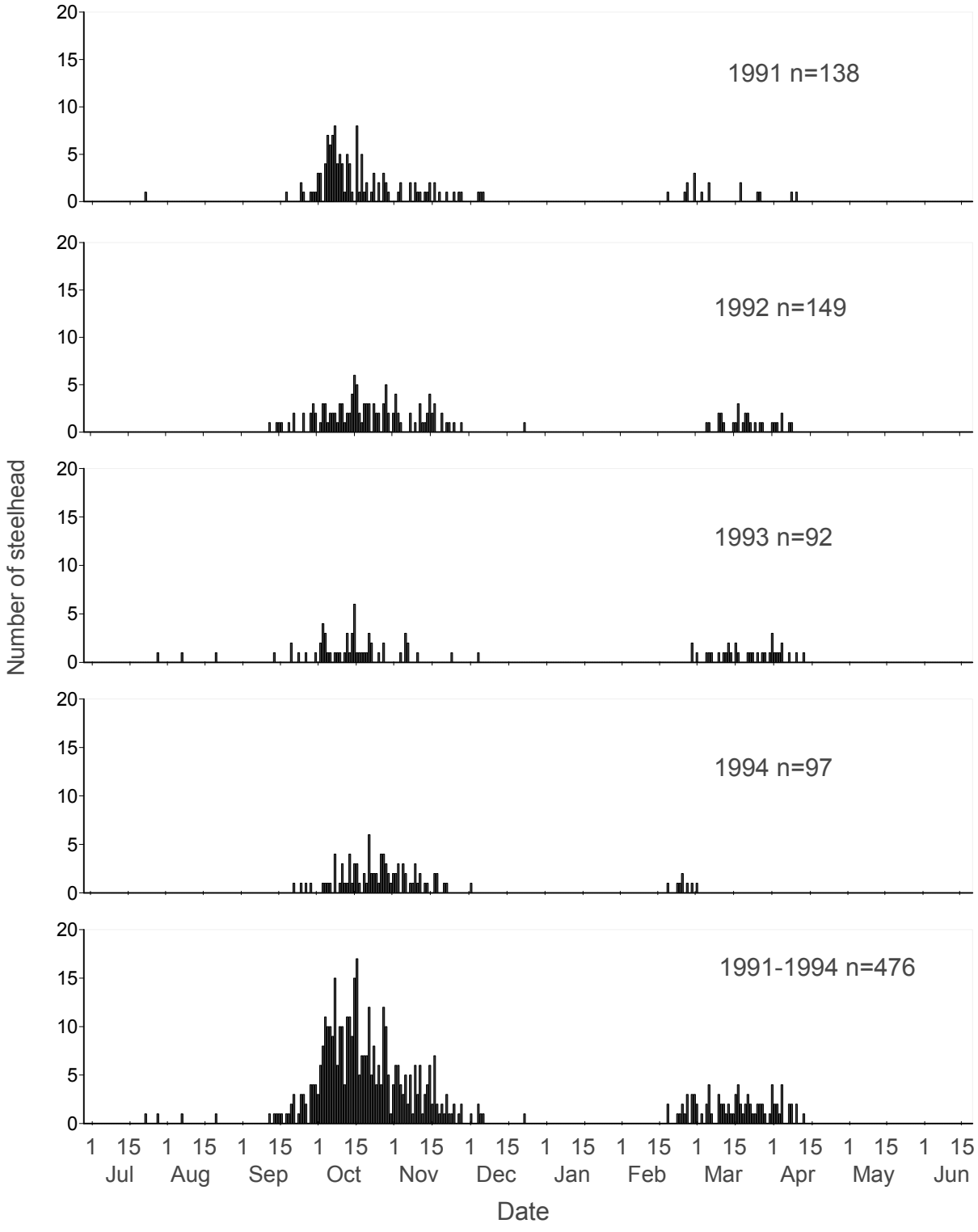

Figure 18. Frequency distribution of arrival dates at Lower Granite Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Clearwater River.

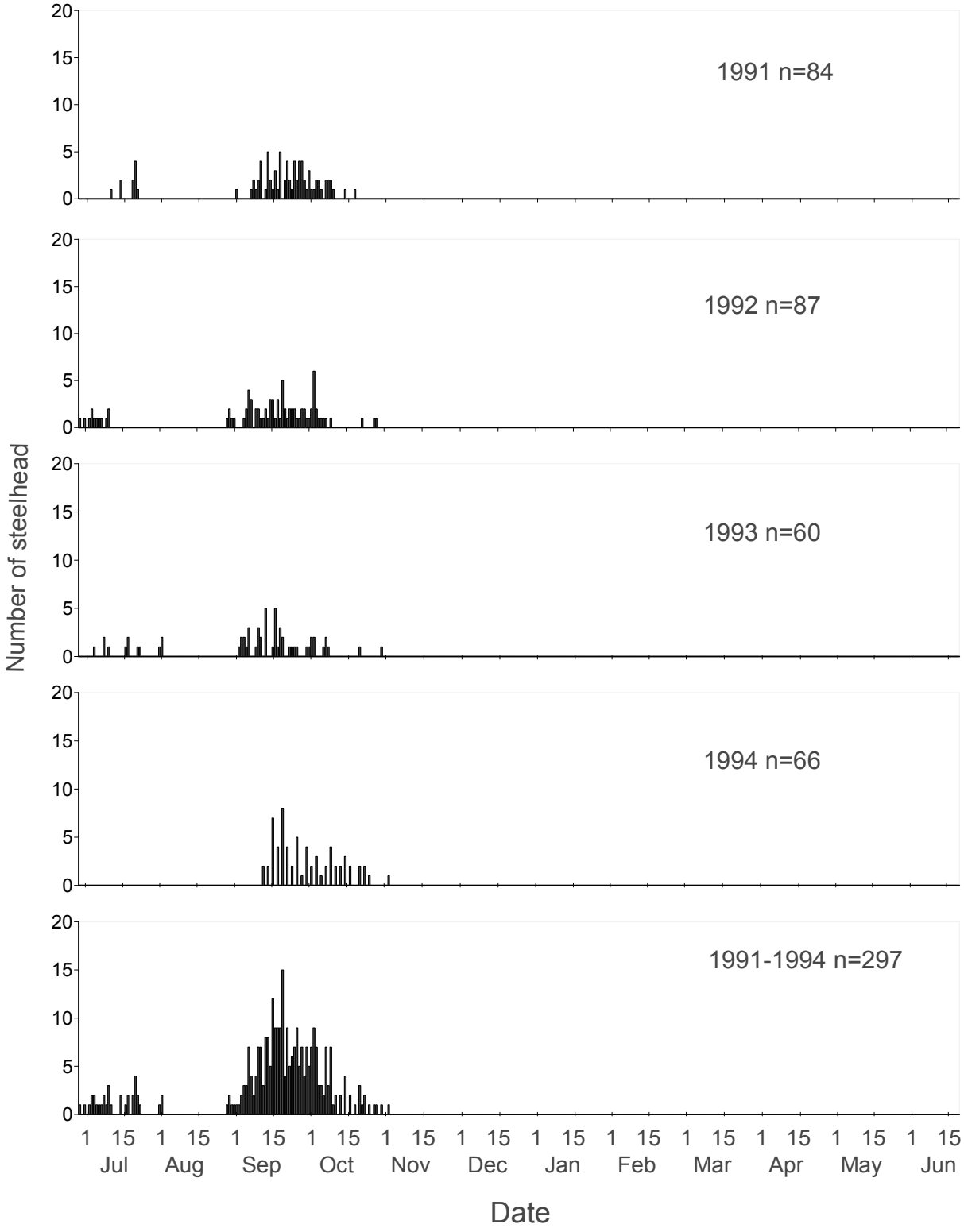

Figure 19. Frequency distribution of arrival dates at Ice Harbor Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Salmon River.

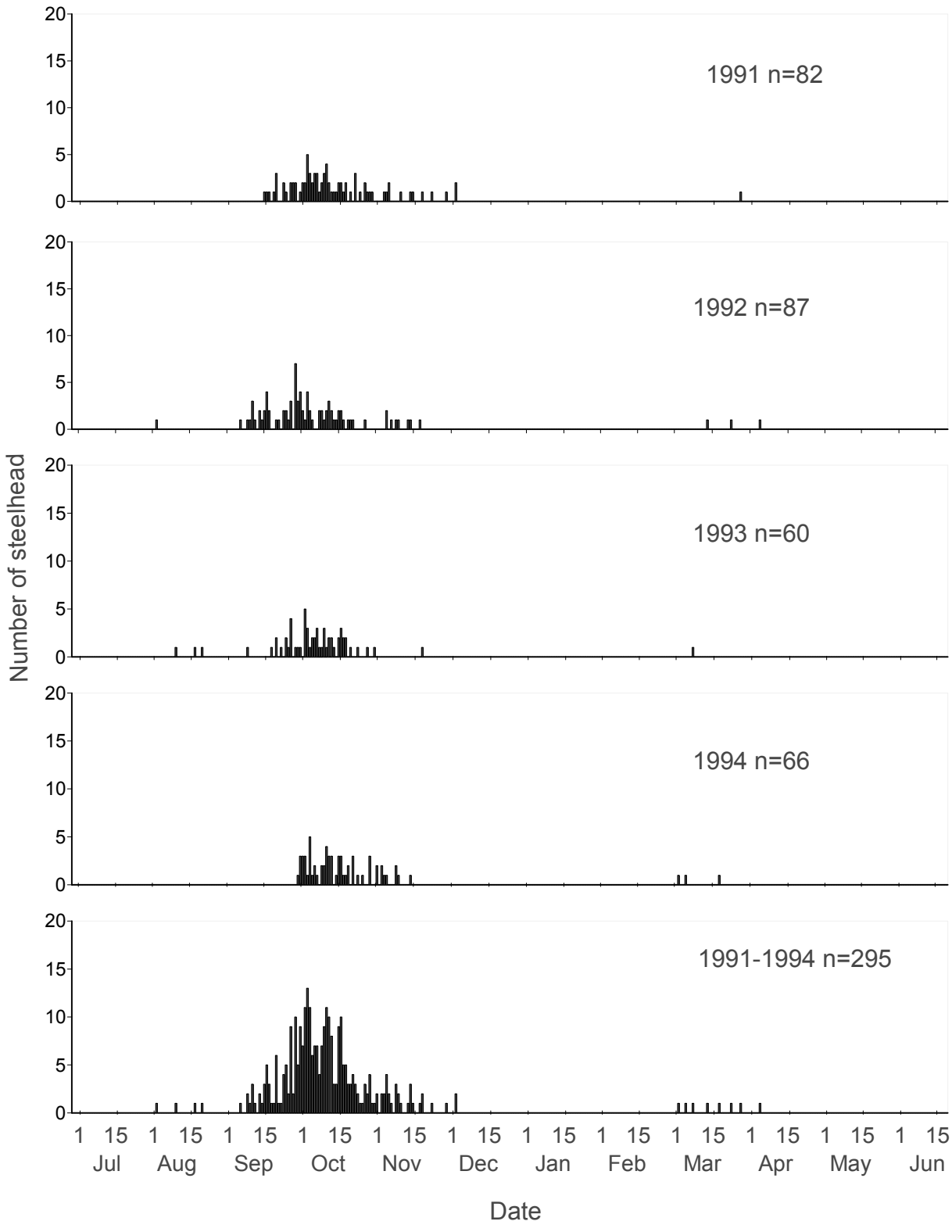

Figure 20. Frequency distribution of arrival dates at Lower Granite Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Salmon River.

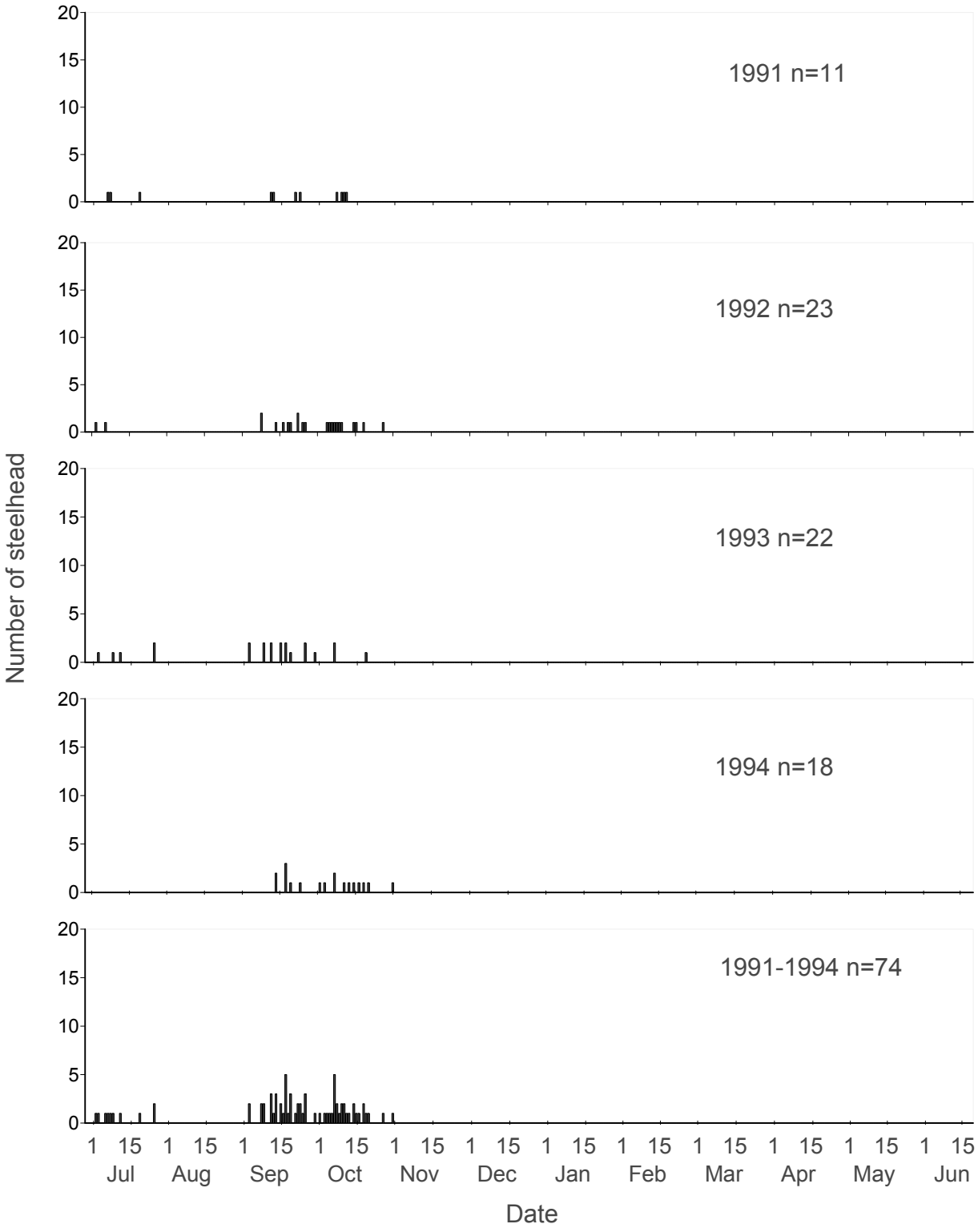

Figure 21. Frequency distribution of arrival dates at Ice Harbor Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Grande Ronde River.

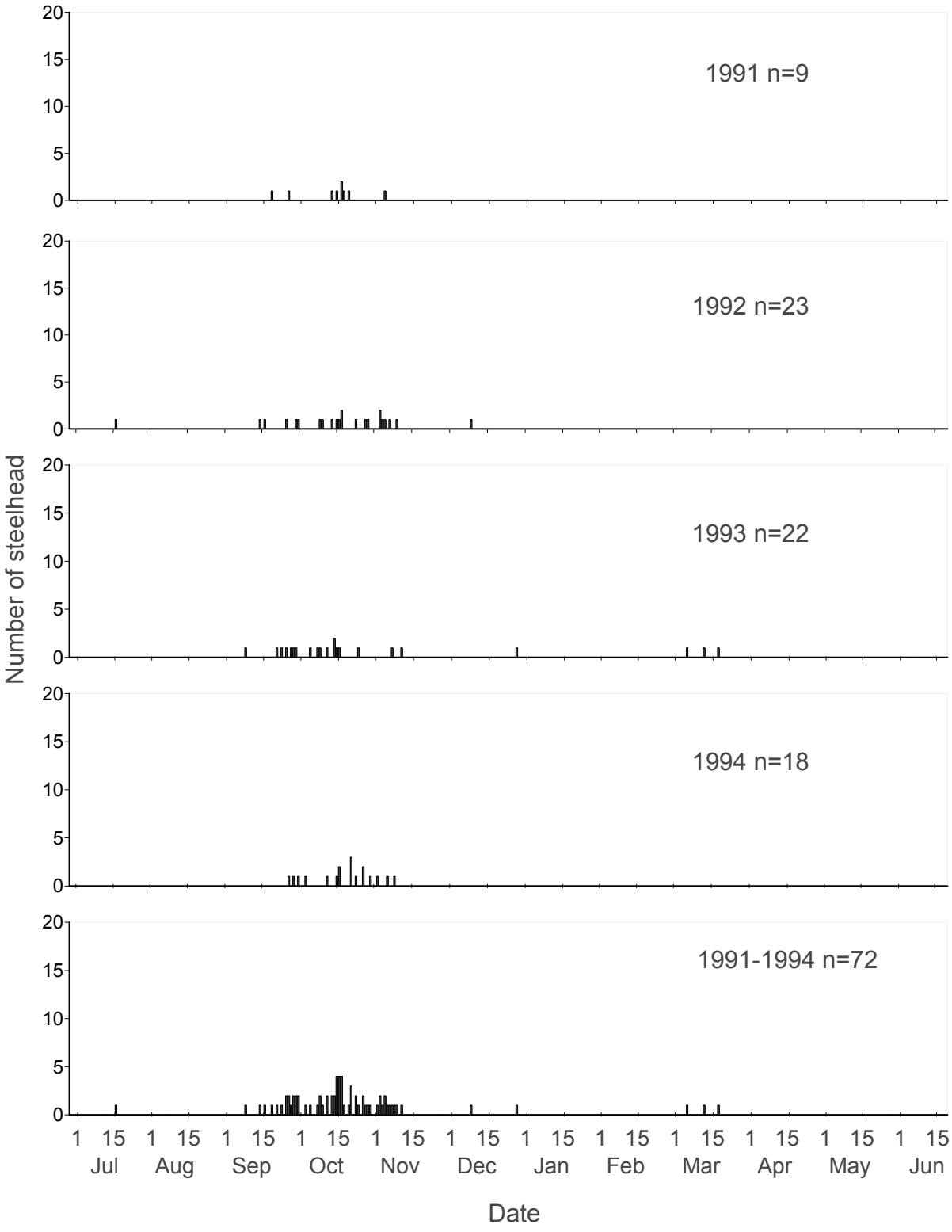

Figure 22. Frequency distribution of arrival dates at Lower Granite Dam by steelhead released in 1991-1994 with transmitters that were last recorded in the Grande Ronde River.

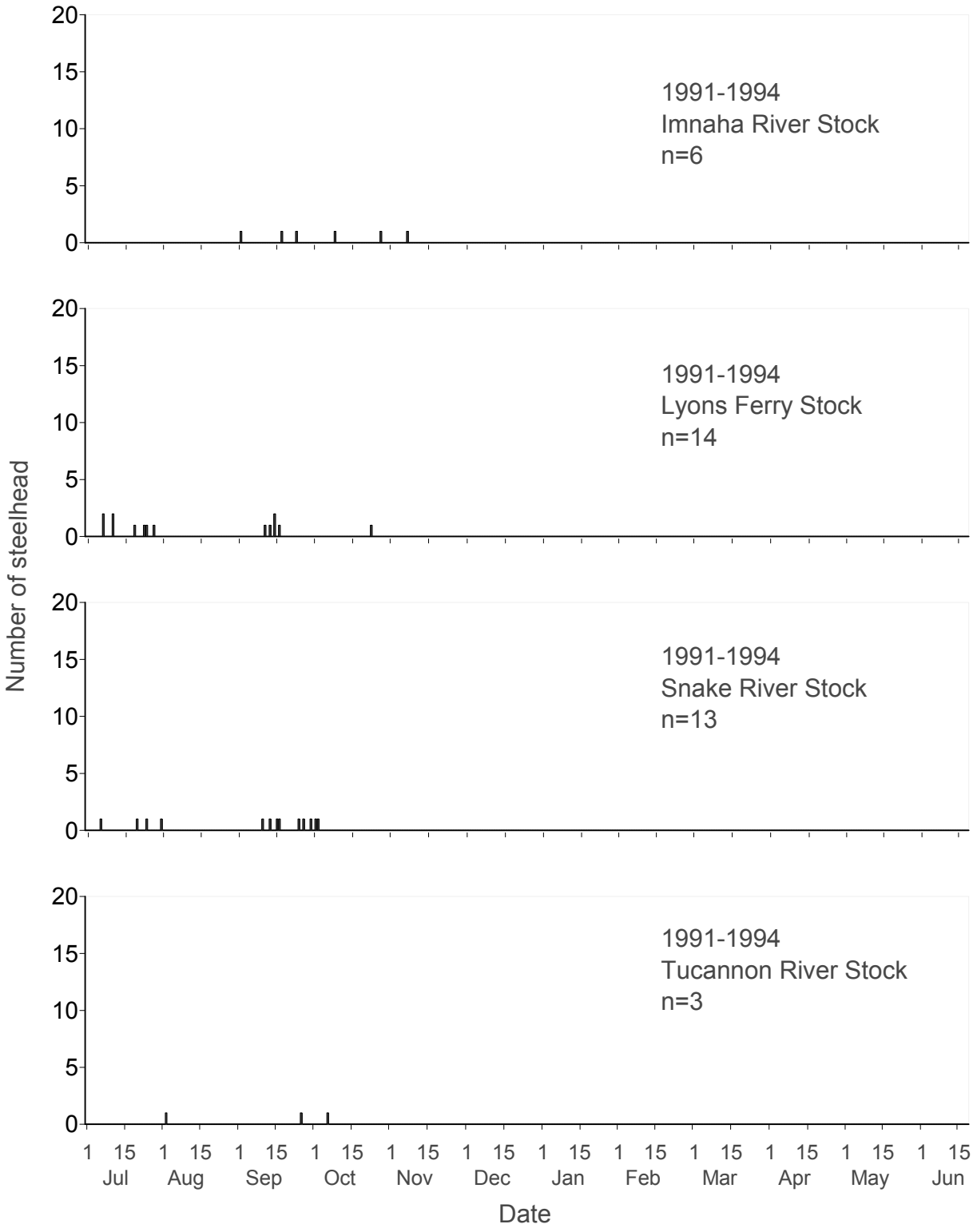

Figure 23. Frequency distribution of arrival dates at Ice Harbor Dam by steelhead released in 1991-1994 that were last recorded in the Imnaha River, Lyons Ferry Hatchery, Snake River upstream from Imnaha River, and Tucannon River.

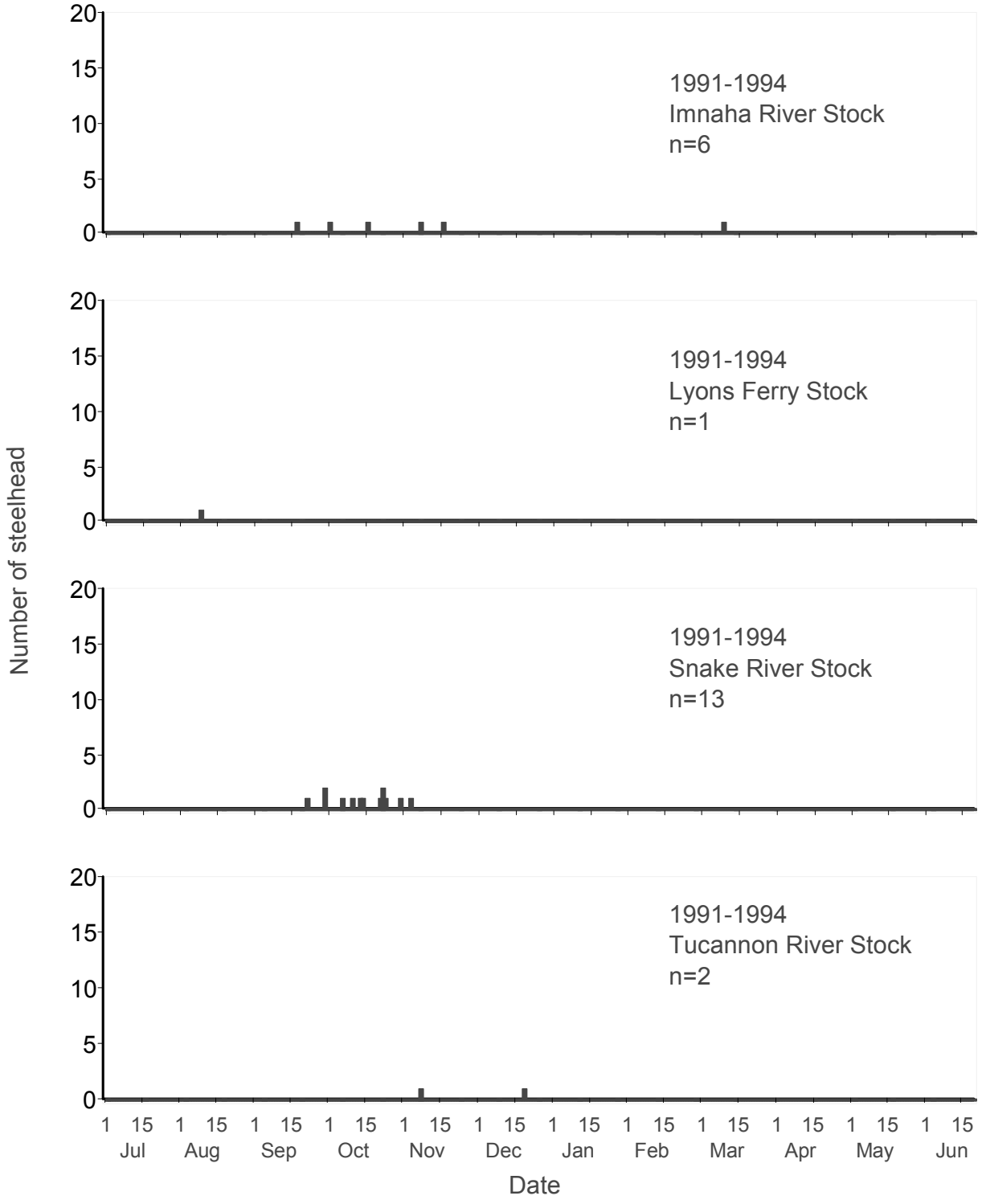

Figure 24. Frequency distribution of arrival dates at Lower Granite Dam by steelhead released in 1991-1994 that were last recorded in the Imnaha River, Lyons Ferry Hatchery, Snake River upstream from Imnaha River, and Tucannon River.

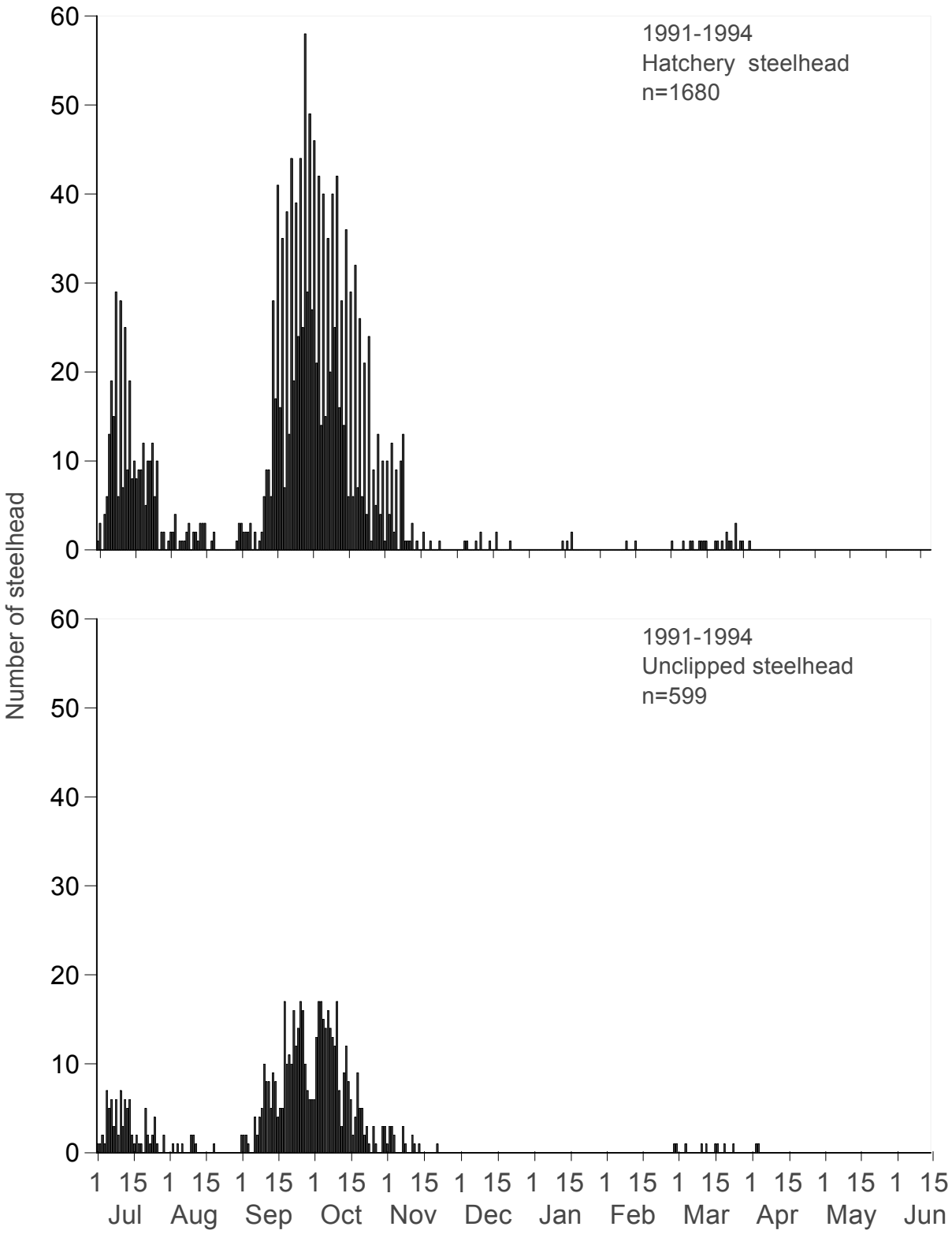

Figure 25. Frequency distribution of arrival dates at Ice Harbor Dam by hatchery and wild (unclipped) steelhead released with transmitters in 1991-1994.

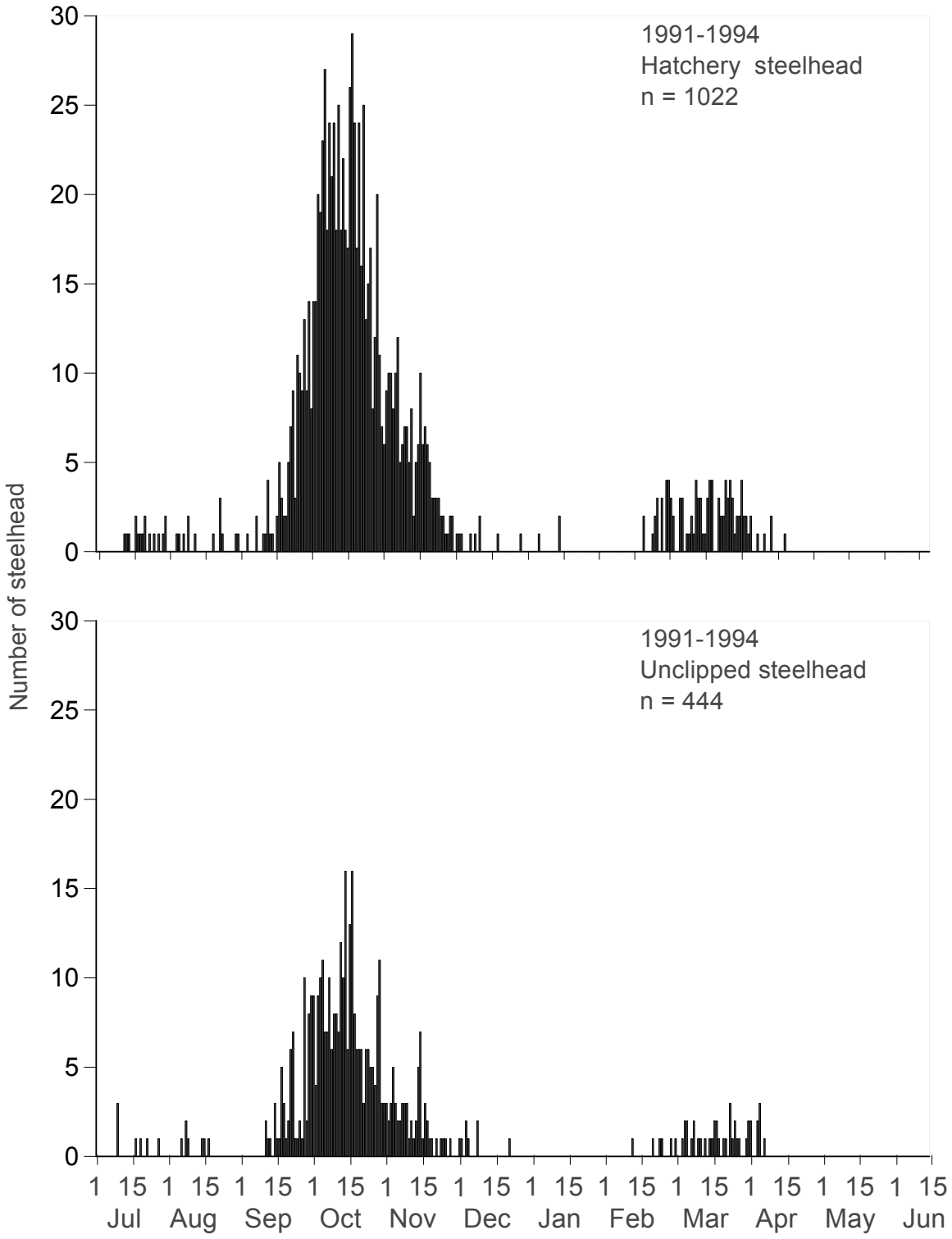

Figure 26. Frequency distribution of arrival dates at Lower Granite Dam by hatchery and wild (unclipped) steelhead released with transmitters in 1991-1994.

Time of arrival at Ice Harbor and Lower Granite dams for hatchery and wild steelhead was similar (1991 through 1994 data pooled, Figures 25 and 26). For example, 98.4% and 98.2% of hatchery and wild steelhead arrived at Ice Harbor Dam prior to 31 December. Similarly, 89.8% and 89.9% of hatchery and wild steelhead arrived at Lower Granite Dam prior to 31 December.

Diel Time of Migration

We used telemetry records at receiver sites to determine if steelhead migrate more actively at specific times of day. Strickland (1967) found no movement at night in the lower Snake River when he tracked steelhead outfitted with sonic tags. Falter and Ringe (1974), however, observed some nighttime movements when they tracked steelhead with sonic tags in the lower Snake River. In this study, steelhead with transmitters were recorded at receivers at tailraces of the four lower Snake River dams at all hours of the day in each of the four years of the study (Figures 27, 28, 29, and 30). More fish arrived during daylight hours, but significant numbers of steelhead entered the tailraces at night. Steelhead exited the tops of fishways predominantly during daylight hours, but a few steelhead exited the fishways at night at the four Snake River dams and at John Day and McNary dams (Figures 27, 28, 29, 30, and 31).

Diel arrival times at receiver sites in the tributaries (Figures 32, 33, 34, and 35) were similar to the timing observed at receivers located at the tailraces of the lower Snake River dams. Steelhead with transmitters migrated past tributary receivers sites throughout the day and night, but most migrated during daylight hours. Both hatchery and wild steelhead had a slight tendency to arrive at tailrace receiver sites at dams and at tributary sites in the PM more than the AM of each day (Table 10). With few exceptions, hatchery and wild steelhead arrived at the various sites at the same time of day.

Timing of Migration Related to Wintering Over

Snake River steelhead are commonly referred to as “summer run steelhead” because they enter freshwater on their spawning migration in the summer and fall and spawn the following spring. As reported above, more than 95% of the Snake River steelhead migrate through the lower Columbia River and enter the Snake River before the onset of winter. Most steelhead (90%) passed the four lower Snake River dams before they stop or slowed their migration for the winter. In late February or March, depending on weather and river temperatures, they resumed active migration to headwater streams where they spawn in April or May.

We were able to estimate where steelhead with transmitters wintered over by examining records of fish as they passed fixed-site receivers and were recorded by mobile trackers throughout the fall, winter and spring. We defined wintering over as a pause in migration of two weeks or more during the late fall or winter months. Steelhead that passed a site in the fall and were not recorded or recaptured at a site further upstream in the spring were not included in the wintering-over analysis. In the Columbia and Snake rivers downstream from Lower Granite Dam, the dams were used to define areas used to winter over. Upstream from Lower Granite Dam, reaches of river where steelhead wintered over were delineated by fixed-site receivers, typically located at the mouths of major tributaries (Table 11, Figure 36). Reaches between fixed-site receivers that were frequently mobile tracked were divided into sub-reaches.

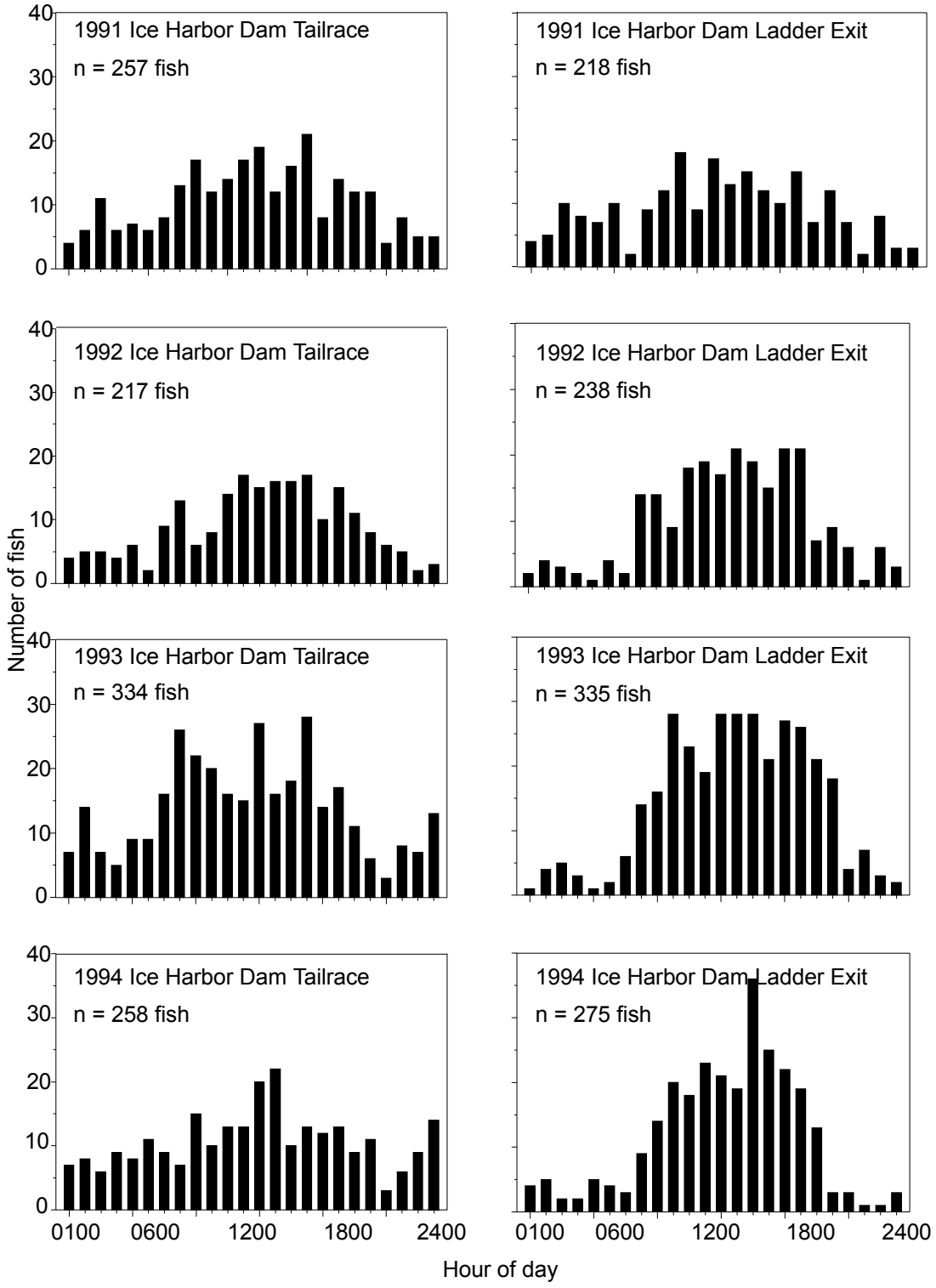

Figure 27. Diel time of migration of steelhead with transmitters past the tailrace receiver site and out the top of the fishways at Ice Harbor Dam in 1991-1995.

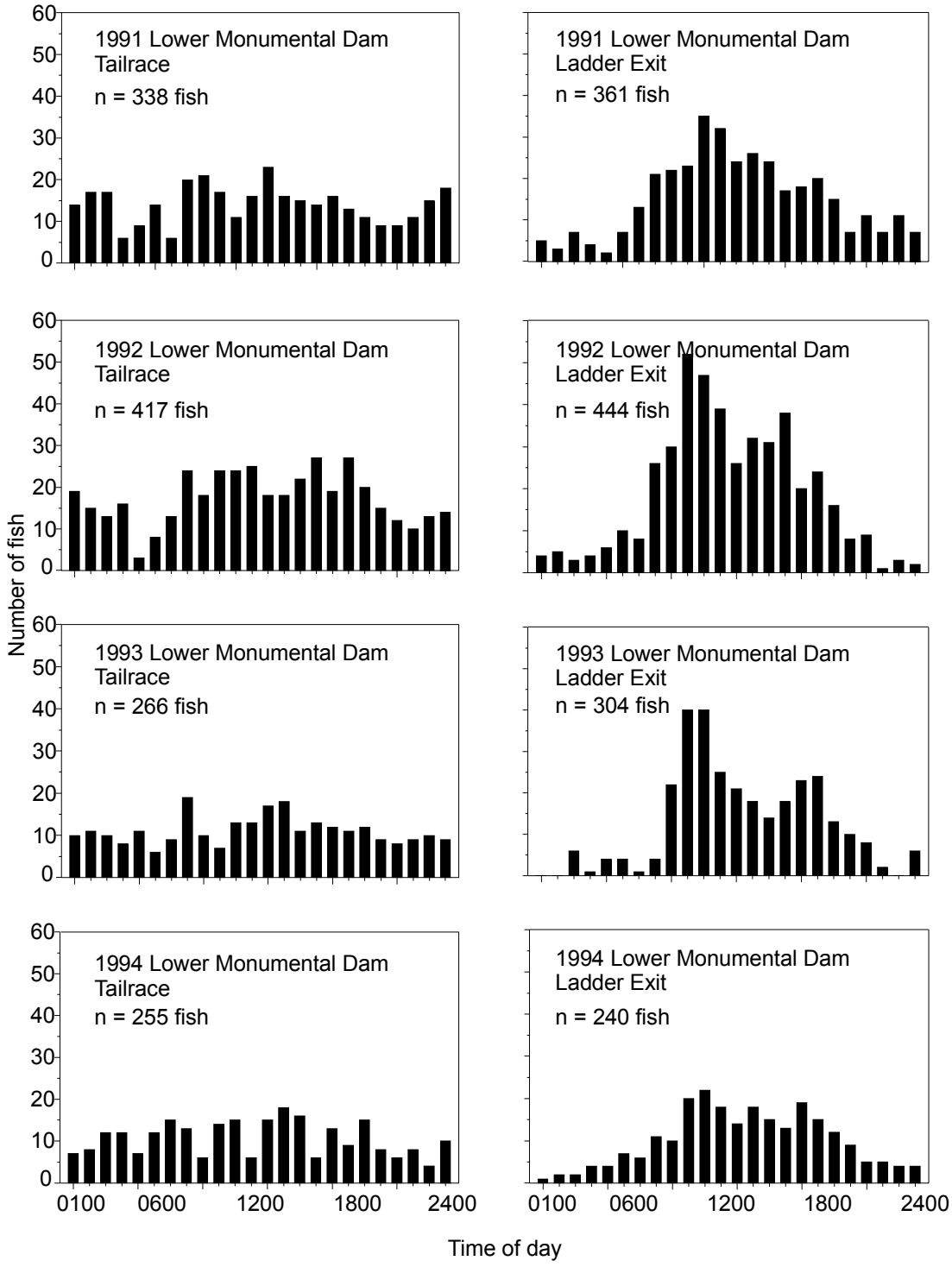

Figure 28. Diel time of migration of steelhead with transmitters past the tailrace receiver site and out the top of the fishways at Lower Monumental Dam in 1991-1995.

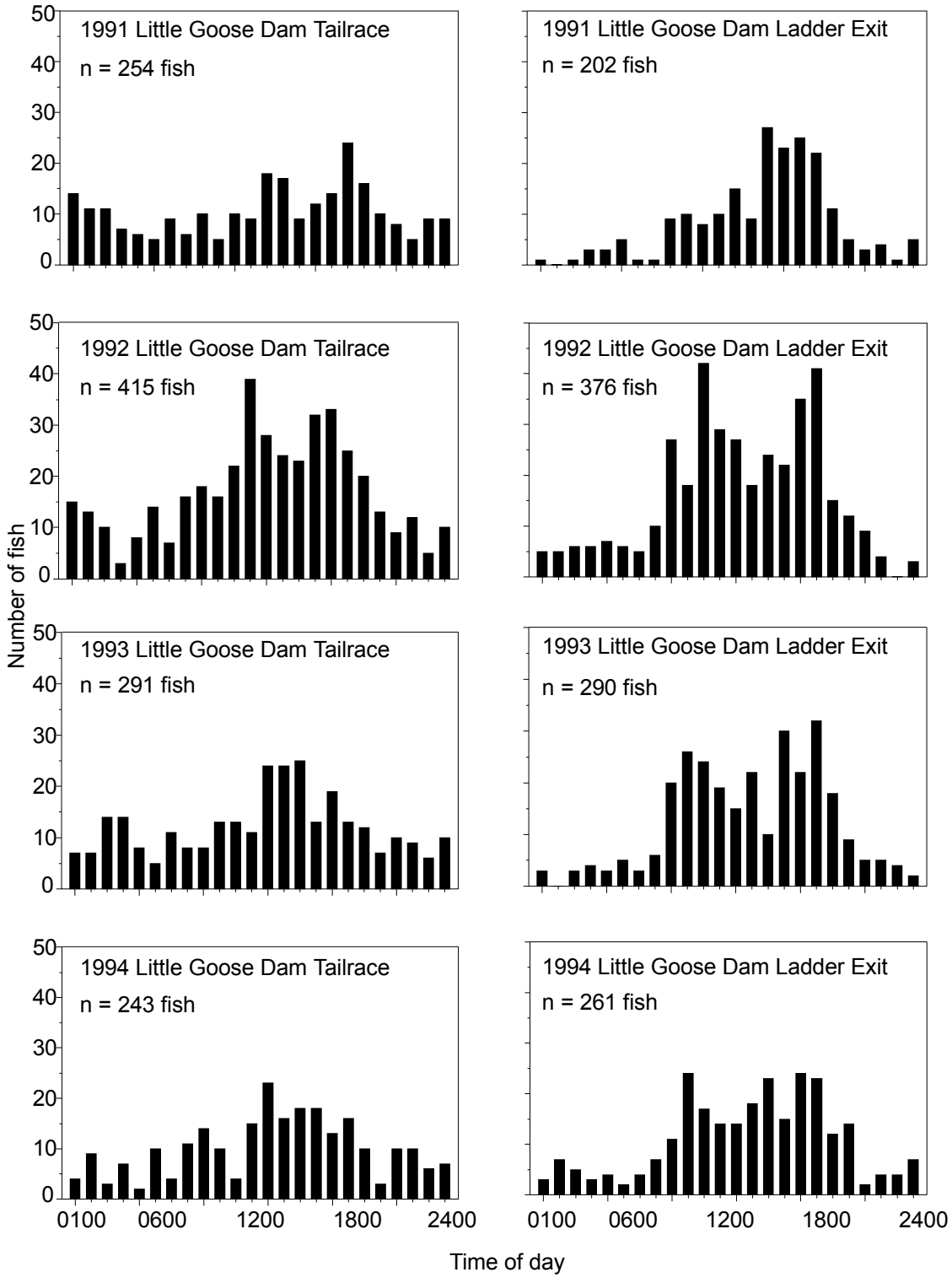

Figure 29. Diel time of migration of steelhead with transmitters past the tailrace receiver site and out the top of the fishway at Little Goose Dam in 1991-1995.

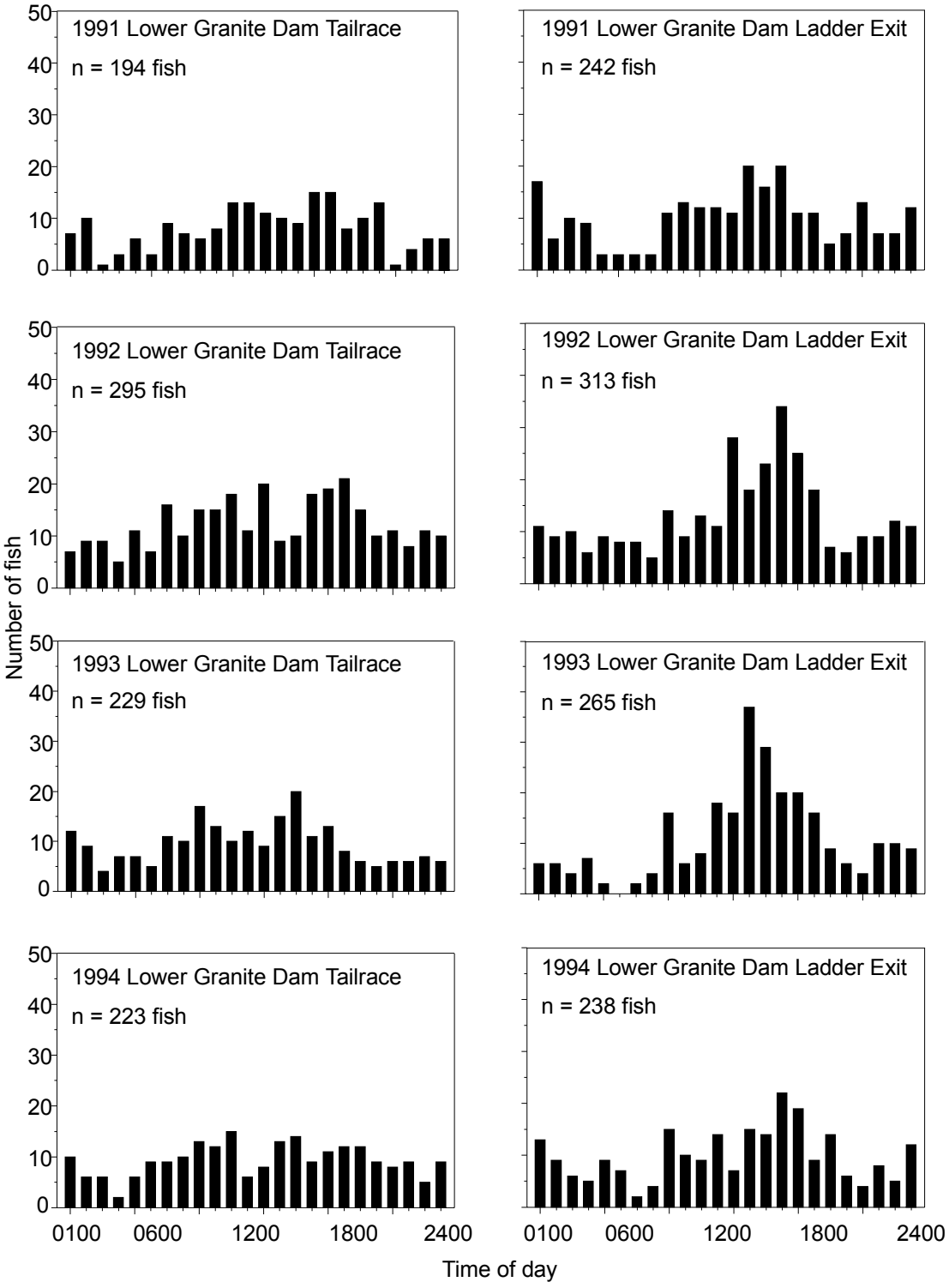

Figure 30. Diel time of migration of steelhead with transmitters past the tailrace receiver site and out the top of the fishway at Lower Granite Dam in 1991-1995.

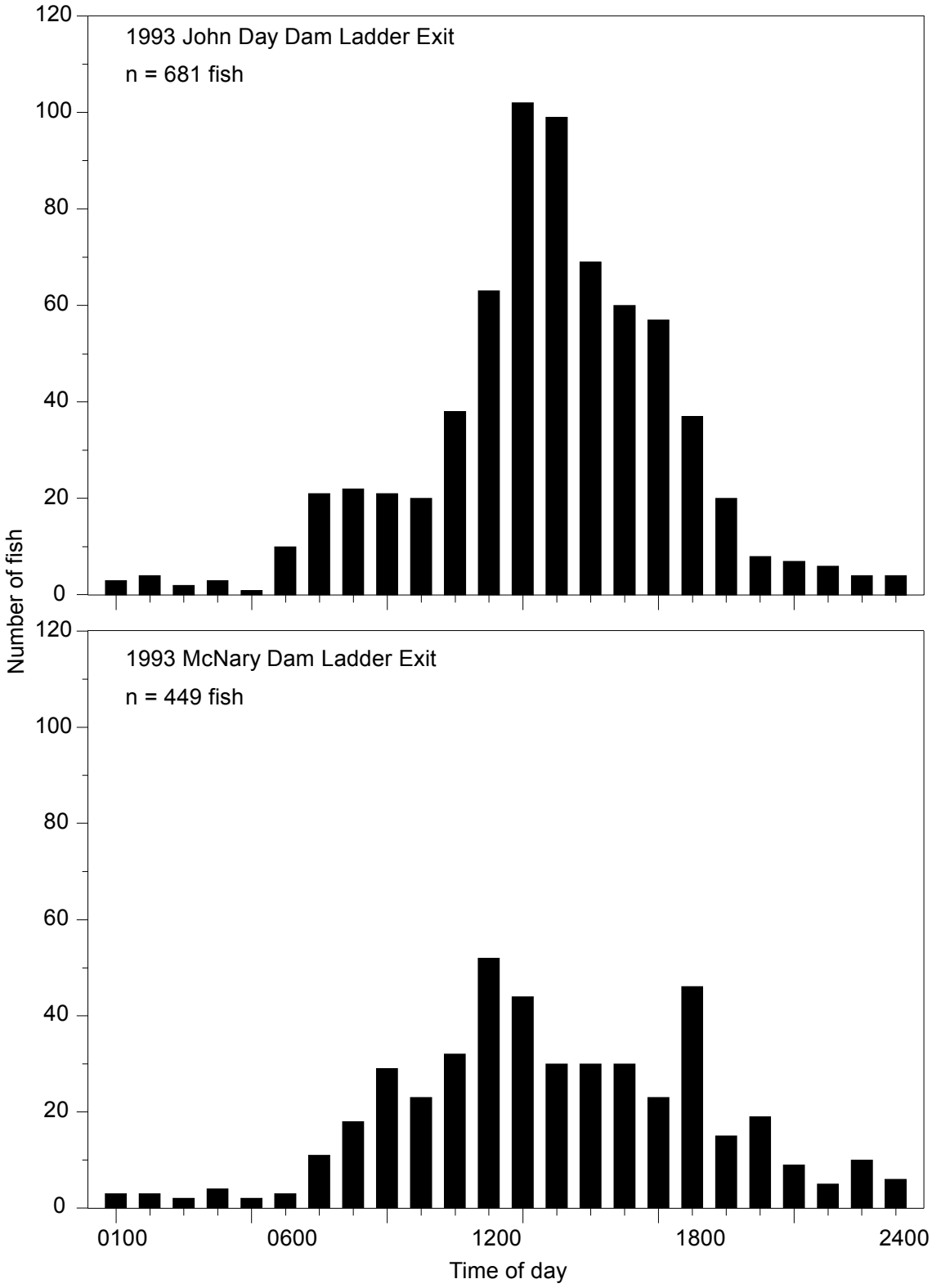

Figure 31. Diel time of migration of steelhead with transmitters out the top of fishways at John Day and McNary dams in 1993.

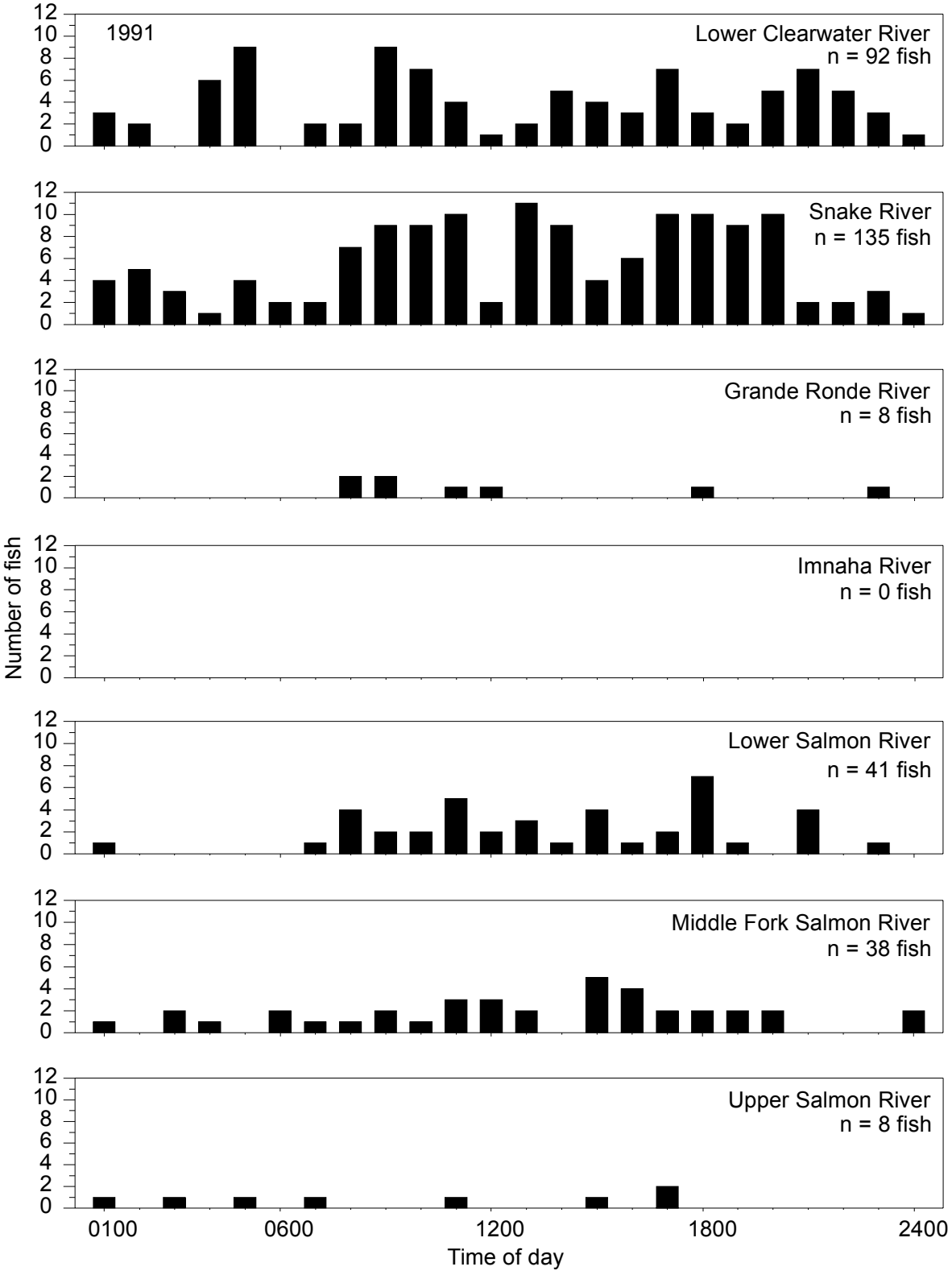

Figure 32. Diel time of migration of adult steelhead with radio transmitters at tributary receiver sites in 1991.

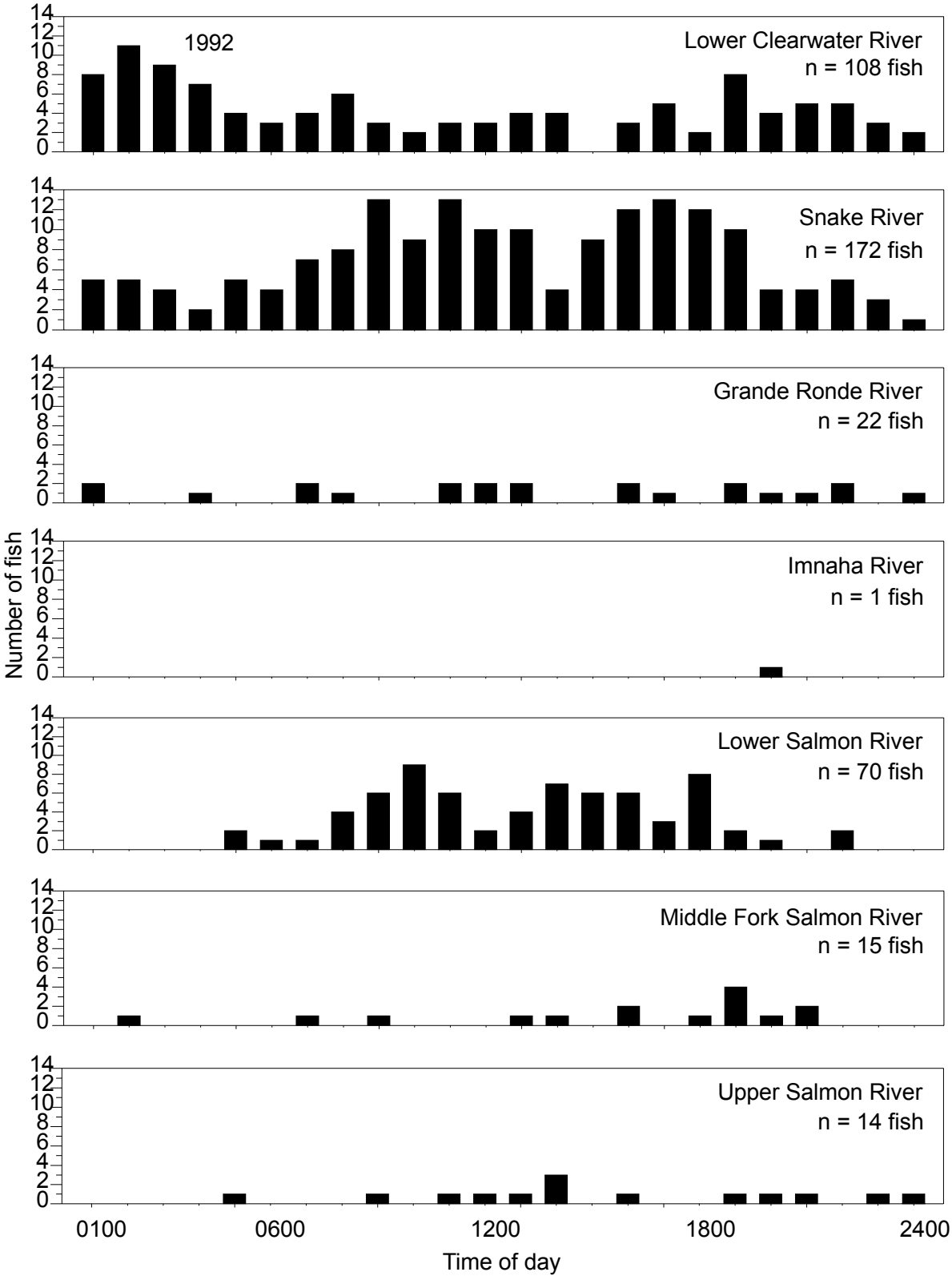

Figure 33. Diel time of migration of adult steelhead with radio transmitters at tributary receiver sites in 1992.

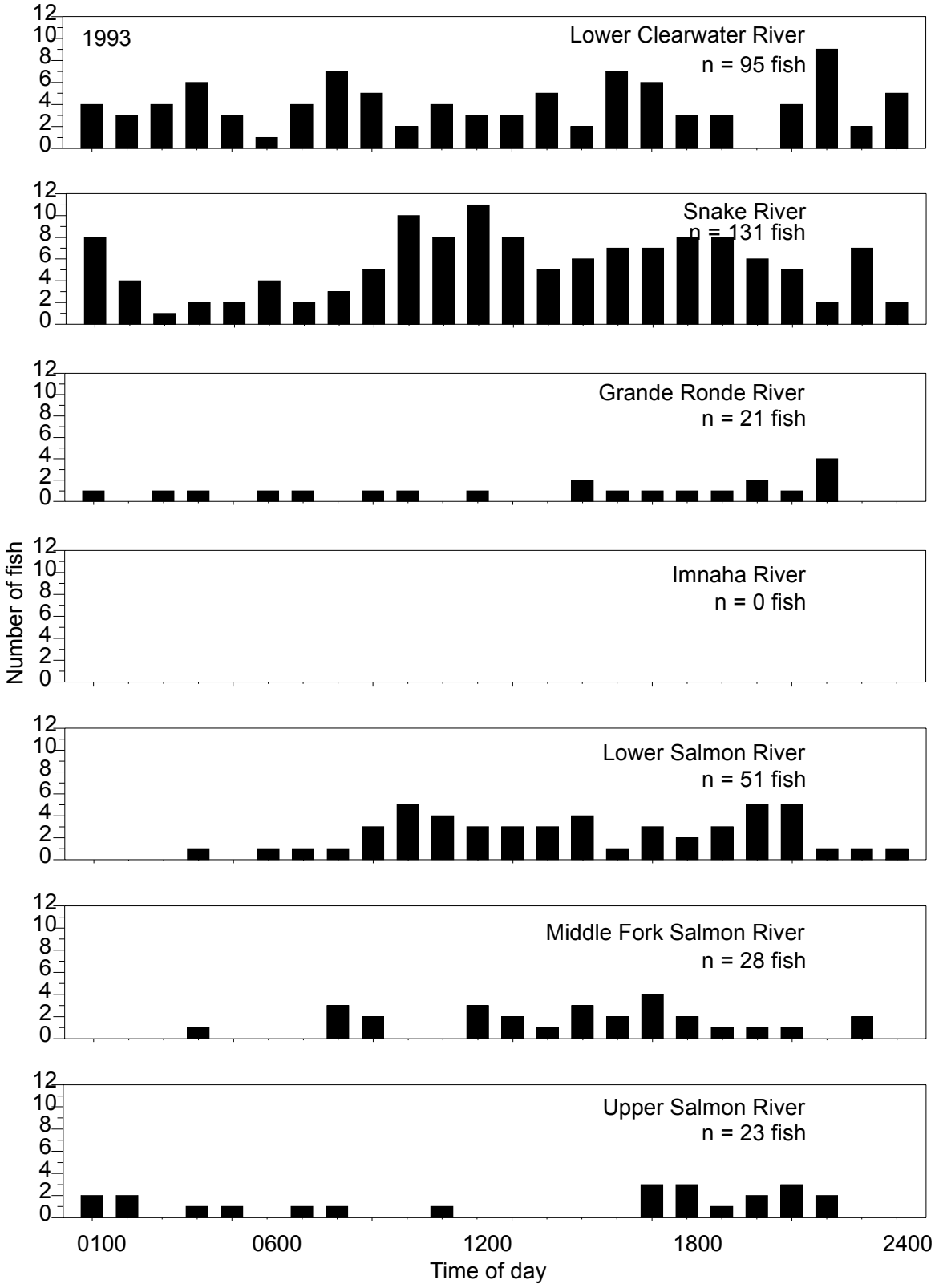

Figure 34. Diel time of migration of adult steelhead with radio transmitters at tributary receiver sites in 1993.

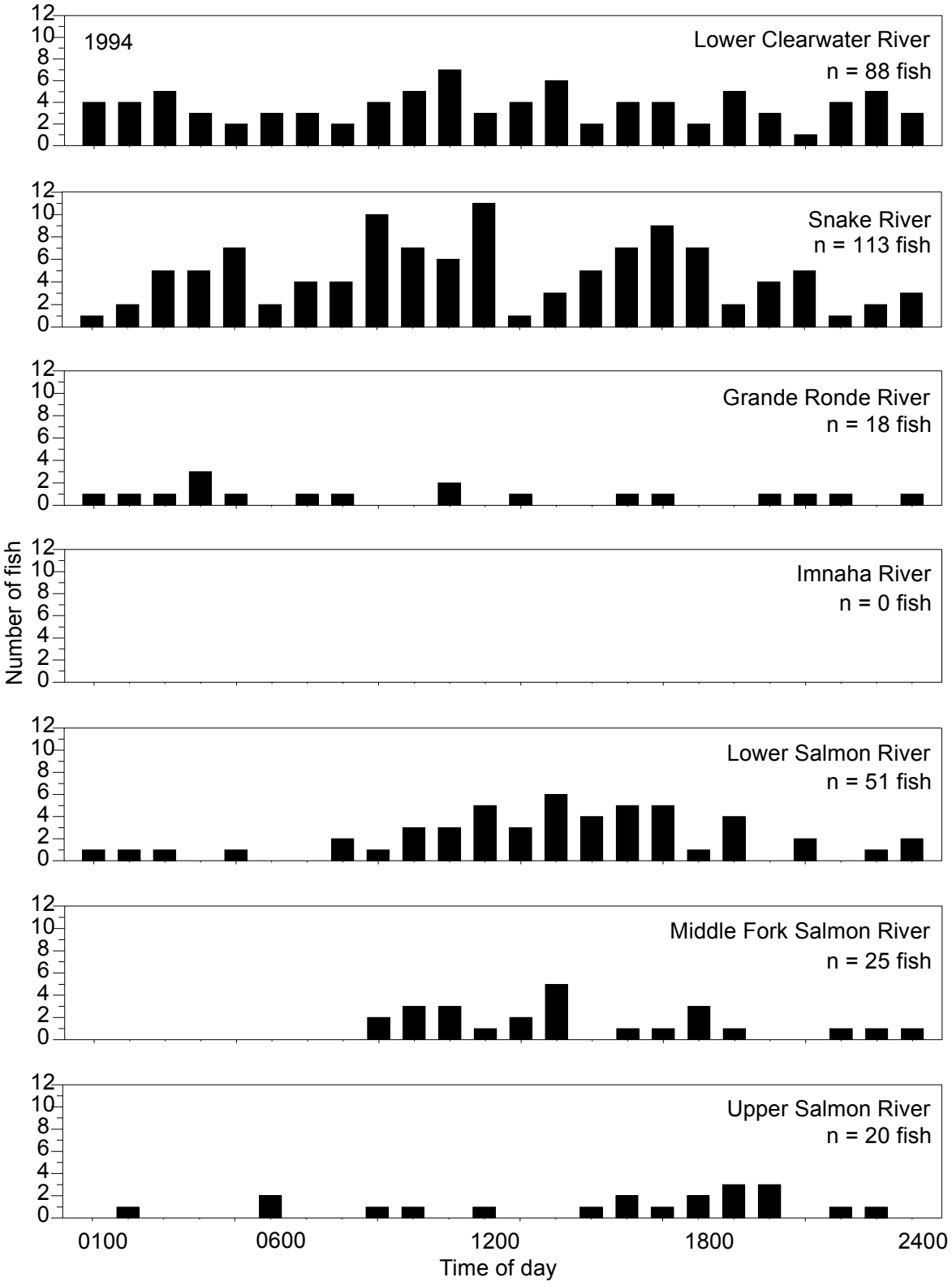

Figure 35. Diel time of migration of adult steelhead with radio transmitters at tributary receiver sites in 1994.

Table 10. Number and percent of hatchery and wild (unclipped) steelhead arriving at receiver sites before noon (AM) and after noon (PM).

	Hatchery			Wild		
Site	n	AM	PM	n	AM	PM
Ice Harbor tailrace receiver	822	46.7	53.3	232	47.4	52.6
Lower Monumental tailrace receiver	910	49.0	51.0	340	48.5	51.5
Lower Goose tailrace receiver	844	39.3	60.7	335	44.8	55.2
Lower Granite tailrace receiver	684	46.5	53.5	236	49.6	50.4
Lower Clearwater receiver	272	46.7	53.3	104	66.4	33.7
Southfork Clearwater River receiver	23	39.1	60.9	5	40.0	60.0
Selway River receiver	1	-	100.0	18	44.4	55.6
Lochsa River receiver	6	33.3	66.6	20	40.0	60.0
Snake River receiver (Asotin, Wa)	368	48.9	51.1	174	47.7	52.3
Grande Ronde River receiver	47	44.7	55.3	20	70.0	30.0
Imnaha River receiver	-	-	-	1	-	100.0
Lower Salmon River receiver	137	37.2	62.8	75	46.7	53.3
South Fork Salmon River receiver	2	-	100.0	15	40.0	60.0
Middle Fork Salmon River receiver	79	35.4	64.6	24	33.3	66.7
Upper Salmon River receiver	55	36.4	63.6	9	44.4	55.6

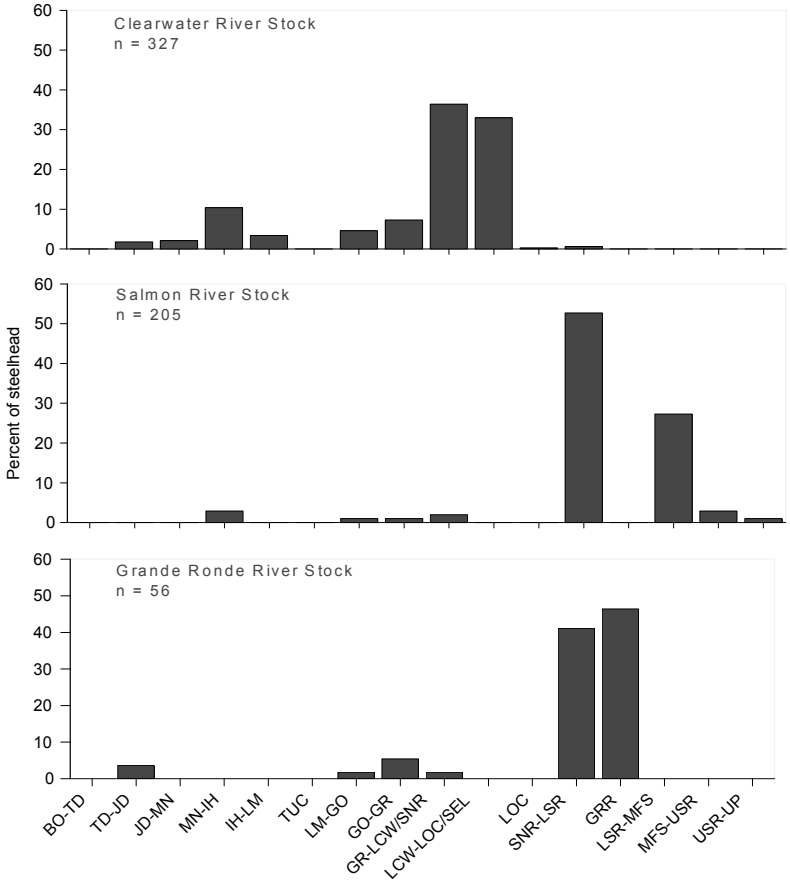

Figure 36. Percent of steelhead released with transmitters in 1991-1994 that ultimately entered the Clearwater, Salmon, and Grande Ronde rivers and the location where they successfully overwintered before resuming their migration to spawning areas.

Table 11. Reaches and sub reaches of the Columbia and Snake rivers where steelhead released with transmitters in 1991-1994 wintered over, listed with their reach abbreviation and distance from the mouth of the Snake River (RKM). Negative RKM values denote sites downstream from the mouth of the Snake River.

Overwinter reach	Reach Abbreviation	Sub-reach	RKMs
The Dalles to John Day dams	TD – JD		-213.5 to -147.7
John Day to McNary dams	JD – MN		-147.7 to -51.8
McNary to Ice Harbor dams	MN – IH		-51.8 to 15.9
Snake River Mouth			0
Ice Harbor to Lower Monumental dams	IH – LM		15.9 to 67.0
L. Monumental to Little Goose dams	LM – GO		67.0 to 113.2
Little Goose to Lower Granite dams	GO – GR		113.2 to 173.0
Lower Granite Dam to confluence of Clearwater and Snake Rivers	GR - LCW/SNR		173.0 to 231.7/233.8
Clearwater River receiver to confluence of Lochsa and Selway Rivers	LCW - LOC/SEL		231.7 to 382.2/384.5
Clearwater River receiver to confluence with North Fork Clearwater River		LCW - NFC	231.7 to 289.3
North Fork Clearwater River to confluence with South Fork Clearwater River		NFC - SFC	289.3 to 344.4
Selway River receiver	SEL		384.5
Lochsa River receiver	LOC		382.2
Snake River receiver to lower Salmon River receiver	SNR - LSR		233.8 to 441.6
Snake River receiver to confluence with Grande Ronde River		SNR - GRR	233.8 to 271.5
Grande Ronde receiver	GRR		273.1
Imnaha River receiver	IMR		331.5
White Bird Creek to lower Salmon River receiver		WBC - LSR	389.1 to 441.6
Lower Salmon River receiver to Middle Fork of Salmon River receiver	LSR – MFS		441.6 to 622.3
Lower Salmon River receiver to Vinegar Creek confluence		LSR - VIN	441.6 to 484.0
South Fork Salmon receiver	SFS		573.2
Middle Fork Salmon receiver to upper Salmon River receiver	MFS – USR	CRN - MFS	622.3 to 682.7
Corn Creek confluence to Middle Fork Salmon River receiver			611.0 to 622.3

Table 12. Percent (number) of adult steelhead released in summer and fall of 1991-1994 with transmitters that wintered over in the various reaches from Bonneville Dam upstream. Overwintering reaches are reaches of river between fixed site receivers and are referenced by site code (see Table 11).

	1991		1992		1993		1994	1991-94	
Reach	Summer	Fall	Summer	Fall	Summer	Fall	Fall	Summer	Fall
BO-TD	-	0.6 (1)	-	-	-	-	-	-	0.1 (1)
TD-JD	-	-	-	-	10.3 (4)	10.6 (23)	0.5 (1)	5.3 (4)	3.0 (24)
JD-MN	-	-	-	-	7.7 (3)	13.9 (30)	0.5 (1)	4.0 (3)	3.9 (31)
MN-IH	5.3 (1)	6.3 (11)	23.5 (4)	9.2 (20)	17.9 (7)	9.2 (21)	6.5 (12)	16.0 (12)	8.1 (64)
IH-LM	-	1.7 (3)	-	2.3 (5)	-	1.9 (4)	1.6 (3)	-	1.9 (15)
TUC	-	-	-	0.5 (1)	-	-	-	-	0.1 (1)
LM-GO	36.6 (6)	6.9 (12)	5.8 (1)	6.0 (13)	5.1 (2)	4.2 (9)	3.8 (7)	12.0 (9)	5.2 (41)
GO-GR	-	9.7 (17)	11.8 (2)	9.2 (20)	2.6 (1)	2.8 (6)	4.9 (9)	4.0 (3)	6.6 (52)
GR-LCW/SNR	21.1 (4)	15.5 (27)	11.8 (2)	25.8 (56)	12.8 (5)	18.1 (39)	23.8 (44)	14.7 (11)	21.0 (166)
LCW-LR/SR	10.5 (2)	25.3 (44)	5.9 (1)	15.7 (34)	5.1 (2)	8.8 (19)	16.2 (30)	6.7 (5)	16.0 (127)
LOC	-	-	-	-	-	-	0.5 (1)	-	0.1 (1)
SNR-LSR	21.1 (4)	20.1 (35)	17.6 (3)	22.2 (48)	17.9 (7)	21.8 (47)	26.5 (49)	18.7 (14)	22.6 (179)
GRR	-	0.6 (1)	11.8 (2)	0.9 (2)	2.5 (1)	3.2 (7)	7.0 (13)	4.0 (3)	2.9 (23)
LSR-MFS	-	12.6 (22)	-	7.8 (17)	15.4 (6)	5.1 (11)	7.6 (14)	8.0 (6)	8.1 (64)
MFS-USR	10.5 (2)	0.6 (1)	-	0.5 (1)	2.6 (1)	-	0.6 (1)	4.0 (3)	0.4 (3)
USR-up	-	-	11.8 (2)	-	-	-	-	2.7 (2)	-
Total number	19	174	17	217	39	216	185	75	792

We assessed wintering-over locations for steelhead with transmitters that were released in summer and fall (for each year and all years combined), by major tributary stock (all years) and by origin (hatchery versus wild).

We were able to locate where 75 of the 609 steelhead released in summer (12.3%) and 792 of the 2,502 steelhead released in fall (31.7%) wintered over for the four years combined (Table 12). Twenty-five percent of the 75 summer-released steelhead wintered over downstream from Ice Harbor Dam, 16% wintered over between Ice Harbor and Lower Granite dams and 59% wintered over upstream from Lower Granite Dam. For fall-released steelhead, 15%, 14% and 71% wintered over downstream from Ice Harbor Dam, between Ice Harbor and Lower Granite dams and upstream from Lower Granite Dam (Table 12).

For steelhead released near Ice Harbor Dam in the summers of 1991, 1992 and 1994 that overwintered, 14% did so downstream of Ice Harbor Dam, 25% were between Ice Harbor and Lower Granite dams, and 61% were upstream from Lower Granite Dam (Table 12). For fall released steelhead in those same years, 8% wintered over downstream from Ice Harbor Dam, 16% between Ice Harbor and Lower Granite dams, and 76% upstream of Lower Granite Dam.

For steelhead released in summer at John Day Dam in 1993, a higher proportion of those that wintered over did so downstream from Ice Harbor Dam (36%) as might be expected because some of those fish were destined for tributaries other than the Snake River. Only 8% wintered over between Ice Harbor and Lower Granite dams and 56% wintered over upstream of Lower Granite Dam (Table 12). A similar distribution of wintering sites was found for steelhead released in fall at John Day Dam, 34% downstream from Ice Harbor Dam, 9% between Ice Harbor and Lower Granite dams and 57% upstream from Lower Granite Dam.

For the four-year period, we determined overwintering reaches for 327 of 491 steelhead whose last telemetry record was in the Clearwater River (Figure 37). Of the 327, 70.3% wintered over upstream of Lower Granite Dam and the remainder wintered over downstream from the dam. The wintering-over locations were subdivided for 245 of the 327 steelhead: 48.6% wintered over in the Lower Granite reservoir and Clearwater/Snake River confluence area upstream to the Snake River receiver site near Asotin WA (SNR; rkm 233.8), and the lower Clearwater receiver site, (LCW; rkm 231.7), 44.1% wintered over in the lower Clearwater River between the LCW receiver site and the LOC and SEL confluence sites and one steelhead wintered over in the Lochsa River. Two Clearwater River steelhead wintered over between Asotin, WA, and the confluence of the Grande Ronde River.

We estimated reaches where 205 of the 297 steelhead that entered the Salmon River during the four-year period wintered over (Figure 37). Most (93.2%) wintered over upstream of the receiver site near Asotin, WA, with 52.7% between the Asotin and Riggins (rkm 441.6) receiver sites. Wintering-over locations were sub divided for 75 of the 205 Salmon River steelhead: 62.2% wintered over between the confluence of Whitebird Creek (rkm 389.1) and the Riggins receiver site and 31.1% were between the Riggins receiver site and the confluence of Vinegar Creek (rkm 484.0). One Salmon River steelhead wintered over in the Clearwater/Snake River confluence, two wintered over between Corn Creek and the Middle Fork Salmon receiver site (MFS), and two wintered over between the SNR receiver site and the confluence of the Grande Ronde River. For 56 of the 70 steelhead that entered the Grande Ronde River, 41.1% wintered over between the Asotin and Riggins receiver sites, and 46.4% wintered over in the Grand Ronde River.

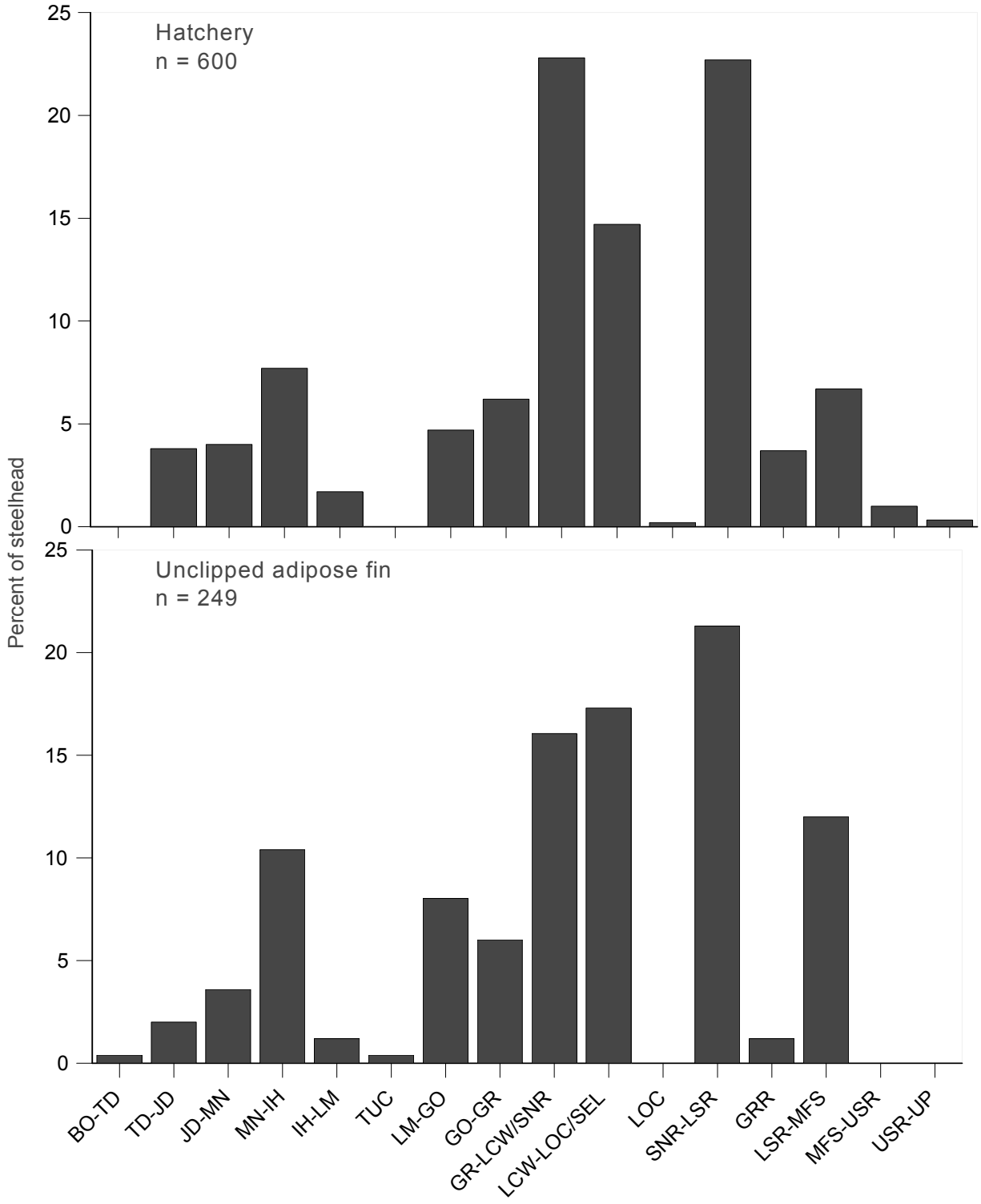

Figure 37. Percent of hatchery and wild steelhead released with transmitters in 1991-1994 and the location where they successfully overwintered before resuming their migration to spawning areas.

Reaches used to winter over by hatchery and wild steelhead was similar for the four-year period (Figure 38). A majority of hatchery (70.5%) and wild (67.9%) steelhead passed Lower Granite Dam before wintering over and similar percentages of hatchery and wild steelhead were found in the different reaches.

Distribution of Steelhead into Tributaries

Distribution of steelhead with transmitters throughout the Snake River drainage was assessed using last known location, based on last record at fixed site receivers, locations by mobile trackers, recaptures by anglers, or recaptures at hatcheries or traps. Distribution of steelhead with transmitters in the Snake River basin was similar in all four years of the study (Tables 13 and 14). Because steelhead were tagged at John Day Dam rather than Ice Harbor Dam in 1993, more steelhead were last located in the Columbia River and tributaries other than the Snake River in that year.

Of the 734 steelhead released with transmitters in 1991, 50 (6.8%) were never located after release (Table 14). Eighty-two (11%) were last located in the Columbia River or tributaries other than the Snake River. Twenty-eight of the 82 steelhead were located downstream and 54 upstream from the mouth of the Snake River. Two hundred and ninety-three steelhead (39.9%) were last located in the lower Snake River between the mouth and Lewiston, ID. Of the 424 steelhead that crossed Lower Granite Dam (58% of those released in 1991), 118 (28%) were last recorded or were recaptured in the Lower Granite Reservoir, 136 (32%) in the Clearwater River basin, 76 (18%) in the Snake River upstream from Lewiston, 12 (3%) in the Grande Ronde River basin, 79 (19%) in the Salmon River basin, and 3 (1%) in the Imnaha River basin (Table 13).

In 1992, 694 steelhead were released with transmitters. Twenty-five (3.6%) of the 694 steelhead released were never relocated (Table 14). Eighty-seven (12.5%) steelhead moved downstream from the point of release and were last located in the Columbia River or in a Columbia River tributary other than the Snake River. Of the 87 steelhead last located outside of the Snake River drainage, 49 were downstream and 38 were upstream from the mouth of the Snake River. Two hundred and thirty-five steelhead (33.9% of those released in 1992) were last located in the Snake River between the mouth and Lewiston, Idaho. Of 425 steelhead that passed Lower Granite Dam (61% of those released), 79 (19%) were last recorded or recaptured in the Lower Granite Reservoir, 160 (38%) in the Clearwater River basin, 80 (19%) in the Snake River upstream from Lewiston, 17 (4%) in the Grande Ronde River basin, 86 (20%) in the Salmon River basin, and 3 (1%) in the Imnaha River basin (Table 13).

In 1993, 884 steelhead were released with transmitters in the south-shore fish fishway at John Day Dam (Table 14). Of the 884 steelhead released with transmitters, 29 (3.3%) were never relocated after release. The only receivers at John Day Dam were at the top of the fishways, so steelhead that moved downstream out of the fishway after release were not known unless located downstream from dam while mobile tracking. Twenty percent of the steelhead (179) moved back down the fishway or fell back over the dam and were last located downstream from John Day Dam: 127 were in the Columbia River downstream from John Day Dam, 51 were in the Deschutes River, and 1 was in the Hood River.

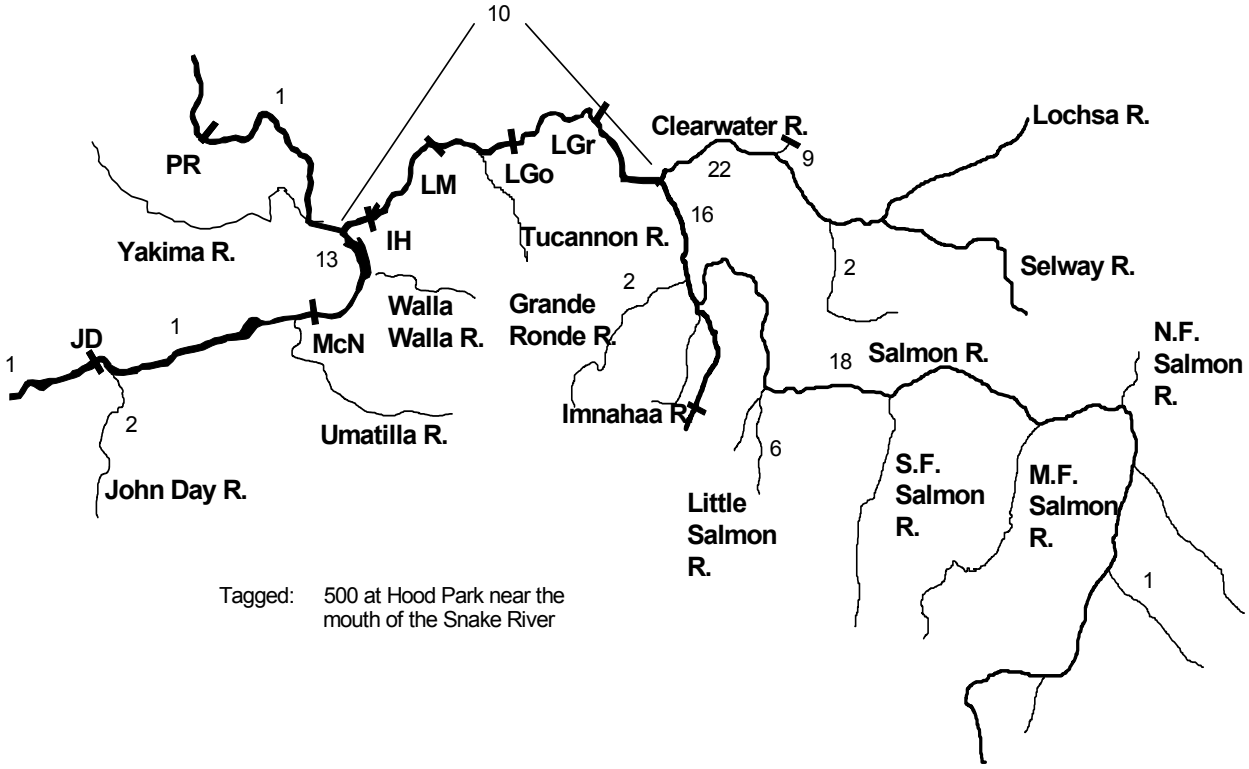

Figure 38. Recapture distribution of adult steelhead outfitted with radio transmitters, released at Hood Park near Ice Harbor Dam, and caught by anglers in 1994.

Table 13. Number of steelhead released in 1991-1994 with transmitters that passed Lower Granite Dam, and the distribution upstream from the dam based on last records at receivers, by mobile tracking, or recaptures by anglers, at weirs, or at hatcheries.

	1991		1992		1993		1994	
Last known location	Number	%	Number	%	Number	%	Number	%
Fish past Lower Granite Dam	424	100	425	100	339	100	332	100
Lower Granite Reservoir	118	28	79	19	67	20	108	33
Clearwater River Basin	136	32	160	38	123	36	106	32
Snake River above Lewiston	76	18	80	19	61	18	50	15
Grande Ronde River Basin	12	3	17	4	22	7	9	3
Salmon River Basin	79	19	86	20	64	19	59	18
Imnaha River Basin	3	1	3	1	2	1	0	0

Twenty-four percent of the steelhead with transmitters (216) were last located in the Columbia River or tributaries to the Columbia River upstream from John Day Dam to the mouth of the Snake River. Of those 216 steelhead, 53 were last located at top-of-fishway receiver sites at John Day Dam, 84 in the Columbia River, 25 at McNary Dam, 38 in the John Day River, 10 in the Walla Walla River drainage, and 2 in the Umatilla River. Four percent of the steelhead (38) were last located in the Columbia River or in tributaries to the Columbia River upstream from the mouth of the Snake River.

Many steelhead released at John Day Dam moved downstream and entered the Deschutes River. We knew from previous studies and angler reports that some steelhead temporarily enter the Deschutes River on their migration through the lower Columbia River. In anticipation that some radio-tagged steelhead might return downstream

and enter the Deschutes River we began mobile tracking the river on 15 July 1993 and tracked the river on 22 days with the last track on 10 May 1994. During that tracking we recorded transmitters for 151 steelhead (17%) that had been released at John Day Dam in summer and fall of 1993. Fifty-five (36%) of the 151 steelhead were last recorded in the Deschutes. Seventeen of the 151 (11%) were recaptured in the Deschutes River, 38 (25%) were not recorded elsewhere outside the Deschutes drainage, and 96 (64%) were recaptured or recorded elsewhere after being in the Deschutes River. Some of the 38 steelhead not recorded elsewhere may have regurgitated their transmitter in the Deschutes River prior to returning to the Columbia River and migrating upstream. Of the 96 steelhead recorded elsewhere, 27 were last recorded in the Columbia River, 12 were in tributaries other than the Snake River (John Day River 5, Umatilla River 1, Walla Walla River 6) and the remainder (57) were subsequently recorded in the Snake River. Based on the fish recorded elsewhere, 38% of the steelhead that moved downstream to the Deschutes River were destined for the Snake River, but that is a minimum estimate. Some of the steelhead recaptured by anglers in the Deschutes and Columbia Rivers and some of the steelhead last recorded in the Columbia River after they were in the Deschutes River were likely of Snake River origin. Seventeen steelhead were caught in fisheries in the Deschutes River, leaving 134 fish in the system that may or may not have been Deschutes River steelhead. Of those 134 fish, 96 steelhead left Deschutes River and 57 (42.5%) eventually returned to the Snake River. Based on this, a minimum estimate 64 (42.5% of 151) of the radio-tagged steelhead recorded in the Deschutes River may have been of Snake River origin, including 7 of the fish caught in fisheries.

Forty-eight percent (422) of the 884 steelhead released with transmitters at John Day Dam were last located in the Snake River drainage. Of the 422 fish, 150 (35.5%) were last located in the Snake River or tributaries between the mouth and Lewiston, ID; the remainder (64.5%) were last located in streams or hatcheries upstream from the confluence of the Clearwater and Snake rivers (Table 14). Of 339 steelhead that passed Lower Granite Dam (38% of steelhead released), 67 (20%) were last recorded or were recaptured in the Lower Granite Reservoir, 123 (36%) in the Clearwater River basin, 61 (18%) in the Snake River upstream from Lewiston, 22 (7%) in the Grande Ronde River basin, 65 (19%) in the Salmon River basin, and 2 (1%) in the Imnaha River basin (Table 13).

Final distribution of the 500 steelhead released with transmitters in 1994 at Hood Park, downstream from Ice Harbor Dam, was similar to that observed in previous years (Tables 13 and 14). Forty-three (8.6%) tagged steelhead were never relocated following release. Thirty-seven (7.4%) transmitters were last located near Hood Park and were probably transmitters that had been regurgitated by steelhead soon after release. Three other steelhead were last located between the mouth of the Snake River and Ice Harbor Dam for a total of 40 last located in that reach.

Fifty-two (10.4%) steelhead were last located in either the Columbia River or a tributary to the Columbia River outside of the Snake River drainage. Forty-four of the 52 steelhead were last located in the Columbia River downstream from the Snake River, four in the Columbia River upstream from the Snake River, two in the John Day River, and one each in the Umatilla and Touchet rivers.

Of the 368 steelhead last located upstream from Ice Harbor Dam, 129 (29%) were in the Snake River or tributaries between Ice Harbor Dam and Lewiston, Idaho.

Table 14. Distribution of steelhead released with transmitters in 1991, 1992, and 1994 near Ice Harbor Dam and 1993 at John Day Dam based on last sittings at receivers, by mobile tracking, or recaptures by anglers, at weirs, or at hatcheries.

Location	1991	1992	1993	1994
Released	734	694	884	500
Columbia River				
Downstream from the Snake River	24	37	211	44
Hood River			1	
Deschutes River			51	
John Day Dam			82	
John Day River			38	2
Umatilla River		2	6	1
McNary Dam			25	
Walla Walla River	4	7	7	
Touchet River		1	1	1
Mill Creek		2	2	
Upstream from the Snake River	54	36	26	4
Yakima River		1	3	
Priest Rapids Dam			2	
Wenatchee River			1	
Wells Hatchery			2	
Methow River			1	
Okanogan River		1	3	
Snake River				
Mouth of Snake River to Ice Harbor Dam	18	30	17	40
Hood Park (not located after release)	48	15		43
Ice Harbor Dam and Reservoir	68	47	20	7
Charbonneau Park (not located after release)	2	10		
Lower Monumental Dam and Reservoir	44	51	25	12
Lyons Ferry Hatchery	10	1	7	4
Palouse River		1		
Tucannon River	1	4	1	1
Little Goose Dam and Reservoir	34	22	13	13
Lower Granite Dam and Reservoir	52	38	17	26
Adult trap at Lower Granite Dam	66	41	50	82
Snake River from Lewiston to Salmon River	49	49	31	26
Receiver site near Asotin	21	27	21	23
Snake River, Salmon R. to Hell's Canyon Dam	2	4	3	1
Hells Canyon Dam	4		6	
Clearwater River drainage				
Receiver site near mouth of Clearwater River	28	19	14	8
Mouth of Clearwater to North Fork of Clearwater	57	69	52	43
Lapwai Creek			1	
North Fork of the Clearwater to Lowell	3	29	4	4
North Fork of the Clearwater River	15	2	2	15
Dworshak National Fish Hatchery	26	5	37	19

Table 14. Continued.

Location	1991	1992	1993	1994
Orofino Creek		1		1
Lolo Creek	1			
South Fork of the Clearwater River	1	9	3	7
Kooskia National Fish Hatchery	1		3	6
Lochsa River	4	13	4	2
Crooked Fork Creek			1	
Selway River	1	12	2	1
Grand Ronde River				
Receiver site, mouth of Grand Ronde River	3	6	10	1
Mouth to Troy, OR	7	6		5
Cottonwood Creek			1	
Wallowa River	2	4	9	3
Bear Creek		1		
Catherine Creek			1	
Prairie Creek			1	
Salmon River				
Mouth to Riggins	15	15	7	13
Receiver site at Riggins	7	9	11	3
Riggins to South Fork of the Salmon River	6	19	7	6
Little Salmon River	2	6	5	13
Rapid River	1	1		
South Fork of the Salmon River	12	5		
East Fork of the South Fork		1		
Johnson Creek		1		
South Fork to Middle Fork of Salmon River		1		
Middle Fork of the Salmon to North Fork	5	7	5	5
Receiver at the mouth of the Middle Fork	16	7	4	1
Middle Fork of the Salmon River				
Marsh Creek		1		
Salmon River upstream from North Fork	9	9	11	8
Receiver at North Fork	4	3	7	
Carmen Creek			1	
Pahsimeroi River	1	1	5	9
Challis Creek				1
East Fork of the Salmon River	1		1	
Imnaha River	3	1		
Little Sheep Creek		2	2	

Of 332 steelhead that passed Lower Granite Dam (66% of steelhead released), 108 (33%) were last recorded or were re-captured in Lower Granite Reservoir, 106 (32%) in the Clearwater River basin, 50 (15%) in the Snake River upstream from Lewiston, 9 (3%) in the Grande Ronde River basin, 59 (18%) in the Salmon River basin, and none were recorded in the Imnaha River in 1994 (Table 13).

Recaptures of Tagged Steelhead

Recapture information was tabulated for steelhead with transmitters during each of the four years of this study. Recapture data for 1991, 1992 and 1993 were presented in previous reports and summaries are presented here for comparison. Data from 1994 have not been presented before and are covered in more detail than data from previous years.

1991

In 1991, we obtained recapture information for 276 (37.6%) of the 734 steelhead released with transmitters (Table 15). Seventy-six percent (209) of the tags (28% of fish released) returned in 1991 were from fisheries, 20% (54) were recovered at hatcheries or traps associated with hatcheries, and the remainder (4%) were from steelhead found dead, transmitters found in rivers throughout the basin, or returned from unknown sources. Thirty-two (11.6%) of the recaptures in 1991 were from the Columbia River or from tributaries to the Columbia River other than the Snake River, and 94 (34.1%) were from the Snake River between the mouth and Lewiston or from tributaries in that section of river; 74 of the 94 were from anglers. Twenty-two (8.0%) recaptures were reported from the Snake River between Lewiston and Hells Canyon Dam, 16 of which were from anglers. Eighty-five (30.8%) recaptures were reported from the Clearwater River drainage, including 55 from anglers and 28 from hatcheries. Five (1.8%) recaptures were reported from the Grande Ronde River drainage; three from anglers and two from hatcheries. Thirty-four (12.3%) recaptures were from the Salmon River drainage, nearly all (32) from anglers.

1992

In 1992, recapture information was obtained for 182 (26%) of the 694 steelhead released with transmitters (Table 15). Sixty-seven percent (122) of the 182 reported recaptures were from anglers and 37 (20%) were from hatcheries or traps associated with hatcheries. Thirty-eight (21%) of the 182 recaptures in 1992 were reported from the Columbia River or from tributaries to the Columbia River outside of the Snake River basin, 34 of them from anglers. Twenty-seven (15%) of the recaptures were from the Snake River between the mouth and Lewiston or from tributaries or hatcheries in that reach. Nineteen of the 27 steelhead recaptured between the mouth of the Snake River and Lewiston were recaptured by anglers versus 74 of 94 in 1991. Ten (5.5%) of the transmitter returns were from the Snake River between Lewiston and Hells Canyon Dam, all but one from anglers. Seventy-five (41%) of the steelhead recaptured in 1992 were recaptured in the Clearwater River drainage. Thirty-nine of the steelhead recaptured in the Clearwater River in 1992 were recaptured by anglers and 25 were recaptured at hatcheries or traps associated with hatcheries. Six (3.3%) of the 182 steelhead recaptured in 1992 were recaptured in the Grande Ronde River drainage, three by anglers and three at hatcheries or traps. Twenty-six (11.0% of 182) fish were recaptured in the Salmon River drainage. Eighteen of the reported recaptures from the Salmon River in 1992 were recaptured by anglers and six were recaptured at hatcheries.

1993

We obtained recapture information for 334 (38%) of the 884 steelhead released at John Day Dam in 1993 (Table 15). Sixty-one percent (204) of the 334 were recaptured by anglers and 24% (82) were recaptured at hatcheries or traps associated with hatcheries.

Table 15. Recaptures of steelhead released with transmitters in 1991, 1992 and 1994 at Hood and Charbonneau Parks and 1993 at John Day Dam with four year total for each location.

		Number of Fish				
Location	Recapture type	1991	1992	1993	1994	91-94
Unknown	Unknown			5		5
Columbia River						
Exact location unknown	Fishery	3		1		4
	Unknown	1				1
Downstream of John Day Dam	Fishery		2	24		26
	Found Transmitter			3		3
Deschutes River	Fishery			13		13
	Trap			2		2
	Found Dead			1		1
	Found Transmitter			3		3
John Day Dam	Trap			4		4
	Found Transmitter			14		14
John Day Dam to Snake River	Fishery	13	18	46	15	92
	Found Dead	1		1		2
	Found Transmitter			1		1
	Unknown		1			1
John Day River	Fishery			11	2	13
	Found Transmitter			1		1
Umatilla River	Fishery		1			1
	Trap		1	6		7
	Found Transmitter			1		1
Walla Walla River	Fishery	3	5	4		12
	Unknown		1			1
Touchet River	Fishery	2		1		3
Columbia R. above Snake River	Fishery	7	7	8	1	23
	Trap	1				1
	Found Transmitter			4		4
	Unknown	1	1			2
Priest Rapids Dam	Found Transmitter			1		1
Wenatchee River	Fishery			1		1
Wells Hatchery	Hatchery			2		2
Methow River	Fishery			1		1
Okanogan River	Fishery		1	3		4
Snake River						
Mouth of Snake R. to Lewiston	Fishery	74	19	28	10	131
	Found Dead	2	3			5
	Unknown	6				6
	Found Transmitter		1	1	2	4
Ice Harbor Trap	Trap	2	2	4	1	9
Lyons Ferry Hatchery	Hatchery	9		2	4	15
	Found Transmitter			5		5
Tucannon River	Fishery	1		1		2
Adult Trap at Lower Granite Dam	Found Transmitter		2	5	5	12
Lewiston to Salmon River	Fishery	15	7	10	16	48
	Found Transmitter		1			1
Salmon R. to Hell's Canyon Dam	Fishery	1	2	3		6

Table 15. Continued

Location	Recapture Type	Number of Fish				
		1991	1992	1993	1994	91-94
Hell's Canyon Dam	Trap	6		6	1	13
Clearwater River	Fishery	41	33	27	22	123
	Found Dead		5			5
	Spawning Ground		4			4
North Fork Clearwater River	Fishery	13	6		9	28
Dworshak Fish Hatchery	Hatchery	27	23	37	19	106
South Fork Clearwater River	Fishery	1			2	3
Kooskia Fish Hatchery	Hatchery	1		3	6	10
Lochsa River	Trap	1				1
	Spawning Ground	1				1
	Found Dead		2			2
Selway River	Trap		2			2
Grande Ronde RIver	Fishery	3	2	3	1	9
Cottonwood Creek	Hatchery			1	1	2
Wallowa River	Fishery		1	1	1	3
	Hatchery	2	2	7	2	13
Lostine River	Trap		1			1
Salmon River						
Mouth to Riggins	Fishery	14	8	3	8	33
	Unknown	1				1
Riggins to Middle Fork Salmon R	Fishery	2	3	2	1	8
Little Salmon River	Fishery	1	2	3	6	12
Rapid River Hatchery	Hatchery	1	4	1		6
Middle Fork Salmon River	Fishery			1		1
Warm Springs Creek	Found Transmitter		1			1
Middle Fk to North Fork Salmon	Fishery	5	2	4	4	15
Salmon River above North Fork	Fishery	8	3	5	5	21
	Spawning Ground		1			1
Carmen Creek	Electroshocking			1		1
Rattlesnake Creek	Electroshocking			1		1
Pahsimeroi River	Fishery				1	1
Pahsimeroi Hatchery	Hatchery	1	2	5	8	16
East Fork Salmon River	Fishery	1				1
Sawtooth Hatchery	Hatchery				2	2
Imnaha River	Fishery	1				1
	Trap	3		2		5

With releases in the Columbia River, 47% (157 of 334) of all reported recaptures were in the Columbia River and its tributaries other than the Snake River. Fifty-two percent (172) of the 334 recaptures were reported from the Snake River basin. Forty-six (14%) of the steelhead recaptured in 1993 were recaptured in the Snake River between the mouth and Lewiston, 29 of them by anglers. Nineteen (6%) of the 334 steelhead were recaptured from the Snake River between Lewiston and Hells Canyon

Dam, 13 by anglers. Sixty-seven (20% of 334) were recaptured in the Clearwater River drainage, 27 by anglers and 40 at hatcheries. Twelve (4%) steelhead with transmitters were recaptured in the Grande Ronde River or its tributaries, four by anglers and eight at hatcheries. Twenty-six (8% of 334) were recaptured in the Salmon River drainage, 18 by anglers, six at hatcheries, and two by electrofishing in small tributaries at spawning time.

1994

Recapture data were returned to us for 155 (31%) of the 500 steelhead with transmitters released in 1994 (Table 15), not including the 337 steelhead that were recaptured and released at the adult trap at Lower Granite Dam. Of the 155 steelhead or transmitters for which we received recapture information, 104 (67%) were recaptured by anglers, 43 (28%) were recaptured at hatcheries or hatchery weirs, seven (4%) were found along rivers and one was recaptured in the Ice Harbor Trap.

Of the 104 steelhead recaptured by anglers in 1994-95, 18 (17%) had dropped back downstream and were recaptured either in the Columbia River or a tributary to the Columbia River other than the Snake River (Table 15). Of the 18 that moved downstream after release, 15 were recaptured in the Columbia River downstream from the mouth of the Snake River, including one near the mouth of the White Salmon River, one in John Day Reservoir and 13 in McNary Reservoir. Two steelhead were recaptured in the John Day River. One steelhead dropped back from the point of release, ascended the Columbia River and was recaptured near the Ringold Hatchery. Ten (9.6%) of the 104 steelhead caught by anglers were recaptured in the Snake River between the mouth and Lewiston, including two in the Ice Harbor Reservoir, four near Little Goose Dam, and three in Lower Granite Reservoir. Sixteen (15%) of the steelhead recaptured by anglers were caught in the Snake River between Lewiston and the mouth of the Grand Ronde River. Thirty-three (32%) of the steelhead recaptured by anglers were caught in the Clearwater River basin. Of the 33 steelhead caught in the Clearwater basin, 22 were captured in the Clearwater River between the mouth and the North Fork of the Clearwater, nine were caught in the North Fork of the Clearwater near Dworshak National Fish Hatchery, and 2 were caught in the South Fork of the Clearwater River. Two (2%) of the steelhead caught by anglers were recaptured in the Grand Ronde River basin, one in the Grand Ronde and one in the Wallowa rivers. Twenty-five (24%) of the steelhead recaptured by anglers were in the Salmon River drainage, including 8 between the Salmon River mouth and Riggins, ID, 1 between Riggins and the South Fork of the Salmon, 4 between the Middle Fork and the North Fork of the Salmon, and 5 in the Salmon River upstream from the North Fork. Six steelhead were caught in the Little Salmon River, and 1 was caught in the Pahsimeroi River.

Reach Survival Estimates

Estimates of survival for steelhead from the top of Ice Harbor Dam to the tops of each of the three dams upstream were calculated from data available on passage of steelhead with transmitters at each of the dams, recaptures of steelhead by anglers and at hatcheries, and passage of steelhead into tributaries (Table 16). Survival was defined as passage through the reach and included steelhead that entered tributaries or hatcheries within a reach. Steelhead that were recaptured in a fishery in the reach or a downstream reach, or entered a tributary downstream from the reach were subtracted from the number listed as having passed the downstream dam in the reach.

Table 16. Reach survival estimates for radio-tagged steelhead released in 1991-1994, with the number that passed each dam, those recaptured in the reach or downstream from a reach, and the number that entered tributaries or hatcheries.

Reach	1991	1992	1993[1]	1994[2]
Ice Harbor - Lower Monumental				
Hood Park releases				
Passed Ice Harbor	282	242		
Passed L. Monumental	261	235		
Recaptured in reach	1	---		
Recaptured downstream	5	1		
Entered tributary downstream	---	---		
Reach survival estimate	**0.946**	**0.975**		
Charboneau releases				
Passed Ice Harbor	265	377		
Passed L. Monumental	240	303		
Recaptured in reach	3	3		
Recaptured downstream	1	7		
Entered tributary downstream	---	6		
Reach survival estimate	**0.920**	**0.839**		
All releases				
Passed Ice Harbor	547	619	414	369
Passed L. Monumental	501	538	396	363
Recaptured in reach	4	3	6	1
Recaptured downstream	6	8	---	---
Entered tributary downstream	---	6	2	---
Reach survival estimate	**0.935**	**0.894**	**0.975**	**0.986**
Lower Monumental to Little Goose				
Passed L. Monumental	501	538	396	363
Passed Little Goose	461	490	367	348
Recaptured in reach	11	7	9	3
Entered reach tributary/hatchery	2	4	7	4
Recaptured downstream	1	---	---	1
Entered tributary downstream	---	2	1	---
Reach survival estimate	**0.947**	**0.934**	**0.969**	**0.981**
Little Goose to Lower Granite				
Passed Little Goose	461	490	367	348
Passed Lower Granite	437	477	354	338
Recaptured in reach	4	2	1	2
Recaptured downstream	6	---	---	---
Entered tributary downstream	---	---	1	1
Reach survival estimate	**0.969**	**0.978**	**0.970**	**0.980**

[1] All 1993 releases were at John Day Dam.
[2] All 1994 releases were at Hood Park.

Survival was defined as the number of steelhead that passed the upstream dam divided by the adjusted number that passed the downstream dam. For the Ice Harbor-Lower Monumental reach, survival was estimated for steelhead released at Hood Park downstream from Ice Harbor Dam and Charbonneau Park upstream from the dam. The numbers listed as having passed Ice Harbor Dam for the Charbonneau Park releases were the numbers released at the Park (Table 16). The numbers listed as having passed Ice Harbor Dam for the Hood Park released steelhead were the numbers that returned and passed the dam. Survival rates of steelhead with transmitters through the reaches between dams in the lower Snake River were in the mid 90% range in all four years, with the exception of steelhead released in summer of 1992 (Table 16). In 1992, only 84% of steelhead released at Charbonneau Park in summer (n = 89) were considered successful migrants from the Park to past Lower Monumental Dam, versus 98% of those released at Hood Park in summer. The reason for the relatively low reach survival rate for the steelhead released at Charbonneau Park was that 61% of the steelhead released at Charbonneau Park in summer returned downstream and fell back over Ice Harbor Dam (Table 1). Of the 59 steelhead released at Hood Park in summer, only 68% eventually returned back upstream and passed Ice Harbor Dam (Table 1). Sixty-two percent of the steelhead released in summer at Charbonneau eventually passed Lower Monumental Dam, and 44% passed Lower Granite Dam, versus 86% and 77% of the steelhead released in fall that passed the two dams (Table 1).

Steelhead released at John Day Dam in 1993 had similar reach survival rates in the lower Snake River to those released near Ice Harbor Dam in the other three years (Table 16). The percentage of steelhead with transmitters released at John Day Dam that eventually passed Lower Granite Dam was lower (28% of summer and 46% of fall released steelhead) than for steelhead released near Ice Harbor Dam (27-46% for summer and 64-84% for fall released steelhead) (Table 1).

In addition to mortality, steelhead designated as not surviving may have been recaptured but not reported, may have entered tributaries or passed dams undetected, or may have regurgitated transmitters but migrated successfully.

Discussion

Advances in radio telemetry technology allowed us to outfit large numbers of steelhead with radio transmitters and follow individual fish for up to a year. In the early years of the project we developed the techniques and acquired the equipment that would allow us to monitor adult steelhead as they migrated upstream in the Columbia and Snake Rivers past dams, through reservoirs, and into spawning tributaries.

Steelhead that are part of the upriver runs (fish destined for tributaries upstream from Bonneville Dam) enter the Columbia River starting in June and continue through October, with peak counts at Bonneville Dam in August and September. Steelhead that pass Bonneville Dam during June, July and most of August have traditionally been called A-group steelhead, and those that pass the dam during late August, September and October are called B-group steelhead. Both steelhead groups migrate part way to their natal streams or hatcheries, winter over in the larger rivers, and then continue their migration and spawn in the spring. Thus, upriver steelhead that enter the Columbia River in summer and fall of one year and complete their migration and spawn the next spring are referred to as fish belonging to a fish year (e.g. 1991-1992). A-group steelhead are produced in most major tributaries in the Columbia basin or in the lower elevation or spring-fed tributaries of the Clearwater and Salmon river basins while B-group steelhead are produced mainly in the colder, high elevation drain-

ages of the Snake, Clearwater and Salmon rivers and their tributaries.

Environmental conditions vary during the time adult steelhead migrate through the lower Columbia and Snake rivers. The earliest migrants may encounter peak flows from snow-melt runoff and relatively cool water temperatures in June. Flows decrease and water temperatures increase as the migration season extends into July and August. Depending on weather, water temperatures in the rivers begin to decline in late August or September. Steelhead may slow their migration through the lower Columbia River and delay entry into the Snake River when high water temperatures persist into September (Peery and Bjornn 2002).

Steelhead enter the Snake River primarily during fall, although some enter in summer and about 5% enter the following spring. Although the number of fish in the A-group run often exceeds the number of B-group fish, by the time they have reach the mouth of the Snake River the two runs have merged and most A-group steelhead enter the Snake River in the fall along with B-group steelhead after water temperatures have started to decline (Peery and Bjornn 2001). Water temperatures in the lower Snake River reservoirs often exceed 20°C during July and August and A-group fish that try to migrate past the dams and through reservoirs during those months are not very successful.

In all four run-years of the study, the proportion of steelhead released in summer with transmitters that completed their migration through the lower Snake River was less (38-67%) than for steelhead released in the fall (64-90%). Many of the summer-released steelhead that successfully migrated through the lower Snake River completed their migration in the fall after moving back downstream and holding temporarily in the cooler Columbia River.

Passages success rates in 1991, 1992 and 1994 were comparable for steelhead released in the same season and at the same location and a high percentage (80 to 99%) of the steelhead that passed one dam on the Snake River passed through the next reservoir and over the next dam upstream. Steelhead released in summer had lower passage success rates than those released in the fall. If A-group steelhead constituted the majority of steelhead tagged in summer, some of those fish would be expected to enter tributaries of the lower Snake River and decrease the percentage of steelhead passing the next dam upstream. Furthermore, some A-group steelhead trapped and tagged at Ice Harbor Dam were likely temporary strays destined for the mid- and upper Columbia River and its tributaries and would not be expected to ascend the Snake River. Steelhead tagged and released at John Day Dam in 1993 exhibited a similar trend after entering the Snake River with summer-released fish having a lower passage success rate than fall-released fish.

Generally, steelhead passed the Snake River dams with minimal delay (median time to pass 0.4 to 0.8 d, same as for adult chinook salmon, Bjornn et al. 1998), and passage times were consistent from year to year and for all dams, except where adult traps were operated. At Ice Harbor Dam, the trap we used to capture fish for the study was located at the top of the south-shore fishway and the fish had to swim through a plexiglass chamber so we could view and divert into a holding pen the fish we wished to tag. The trapping apparatus facilitated capture of the fish with minimal stress on the fish, but the viewing chamber reduced the passage area in the fishway and slowed passage. There was evidence after the first year that some fish were migrating up the fishway to the trap and then moving back down the fishway. As a consequence, median passage time for steelhead the first year was about two days. In 1994, when trapping was minimized (fewer hours and alternate days) the passage time was 0.5 d, similar to the other dams without traps. At Lower Granite Dam passage times were extended (1.0 to 1.6 d median

time) in all four years for steelhead that were diverted into the trap adjacent to the fishway. Steelhead that were not diverted probably had passage times similar to those at other dams, but we could not assess the time because all steelhead with radio transmitters or secondary tags were diverted into the trap to inspect for transmitter loss.

There were no apparent differences in time to pass the dams for steelhead released in the summer versus those released in the fall or for steelhead migrating in the fall versus those migrating in the spring. Additionally, time required to pass the dams were similar for steelhead of hatchery or wild origin. Again, at Ice Harbor and Lower Granite dams where adult traps were operated, median times to pass were consistently higher than at Lower Monumental and Little Goose dams

Unlike dam passage times, steelhead migration rates through the lower Snake River reservoirs varied by season of migration. Steelhead released with transmitters in summer migrated through the three lower reservoirs mostly in the summer and fall at rates of 20-29 and 27-33 km/d, respectively. The few steelhead released in summer that took two seasons (summer and fall) to migrate through a reservoir had slow migration rates (0.5-2.0 km/d). Steelhead that migrated through the reservoirs the following spring had migration rates (16-46 km/d) that exceeded those of fish that migrated through the same sections of river in the summer or fall.

Steelhead released in the fall migrated through the reservoirs mostly in the fall at rates of 19-36 km/d, with smaller numbers the following spring at rates of 35-40 km/d. Steelhead migration rates through the three lowest Snake River reservoirs were about half the speed of spring and summer chinook salmon, and perhaps reflects a lesser migration imperative for steelhead in the lower Snake River that interrupt their migration to winter over (mostly upstream from the dams). Spring/Summer chinook salmon, on the other hand, must pass through the lower Snake River and reach spawning tributaries by late summer. The reservoir migration rate of steelhead in spring (March and April) when they have resumed their migration to natal streams does not match that of spring and summer chinook salmon, perhaps because water temperatures are colder than when the chinook migration occurs (April to July).

The difference in migration rates of steelhead with transmitters through Lower Granite reservoir to the Snake River site at Asotin or the Clearwater River site versus rates through the lowest three reservoirs could be related to both the stocks involved and the fact that many steelhead winter over in Lower Granite Reservoir and near the confluence of the Snake and Clearwater rivers. For the four years, steelhead released in the fall that migrated into the Clearwater River in the fall had a median migration rate though Lower Granite Reservoir of 7 km/d; those that continued up the Snake River past the Asotin receiver site had a rate of 17 km/d, versus rates of 20-36 km/d for steelhead released in the fall that migrated through the other three reservoirs in the fall. Steelhead released in the fall that migrated through Lower Granite Reservoir in the spring and entered the Clearwater River or continued up the Snake River had more rapid migration rates of 35 and 24 km/d. Clearwater River steelhead slowed their migration through Lower Granite Reservoir in the fall prior to wintering over and a higher proportion migrated in the spring compared to steelhead heading to tributaries of the Snake River upstream from Asotin. Steelhead destined for these tributaries migrated through the Lower Granite Reservoir and into the free-flowing Snake River before slowing their migration in preparation for wintering over.

In all four years, steelhead that crossed Lower Granite Dam and were recorded at the receiver site in the lower Clearwater River upstream from the Potlatch Mill in the

summer or fall migrated at slower rates (1.7 to 8.4 km/d, Table 4) than steelhead migrating past the receiver site on the Snake River near Asotin at the same time of year (15 to 27 km/d). Steelhead destined for the Clearwater River moved slowly through Lower Granite Reservoir with up to 28% of the steelhead recorded at the Clearwater River site recorded in the spring. Steelhead destined for Snake River tributaries such as the Grande Ronde and Salmon rivers moved more rapidly through the reservoir and the Snake River, with no more than 9% passing the Asotin site in the spring.

Passage times for hatchery and wild steelhead with transmitters in each lower Snake River reservoir were similar with the exception of the Lower Granite Dam to Clearwater River reach where hatchery and wild steelhead had median passage times of 11.15 d and 4.46 d, respectively. Slower median passage times for hatchery steelhead in this reach could be related to the high number of Dworshak and Kooskia National Fish Hatchery steelhead that wintered over in the Lower Granite reservoir. Median passage times for the reach from Lower Granite Dam to the Clearwater River receiver were also longer than those of any other reservoir including the Lower Granite Dam to Snake River receiver reach. Most of the steelhead that wintered over between Lower Granite Dam and the Clearwater and Snake River receiver sites eventually entered the Clearwater River in the spring and did not influence passage times from Lower Granite to the Snake River receiver.

Steelhead migration rates through free-flowing sections of river upstream from Lower Granite reservoir were variable and appeared dependent on the stock of steelhead involved, the time of year fish reached the free-flowing river and the proportion that wintered over in those reaches of river. Sample sizes were small but generally steelhead tagged in summer that migrated through the free-flowing reaches before 31 December migrated at faster rates than steelhead released in the fall that migrated in the fall. Steelhead migrating in the spring after wintering over had the highest migration rates. Comparisons were difficult to make due to large numbers of steelhead wintering over in free-flowing river reaches and therefore having extended migration times. Removal of overwintering steelhead from analyses reduced sample sizes to unacceptable levels. Comparison of passage times through free-flowing river reaches for steelhead of hatchery and wild origin was also difficult due to small sample sizes for many river reaches despite combining data for all study years. We did not find consistent differences between hatchery and wild steelhead migration rates. This was not surprising because these hatchery steelhead came from wild upriver stocks and would be expected to behave similarly.

The percentage of steelhead that fell back at each of the lower Snake River dams from 1991 to 1994 ranged from 2.2 to 5.9% (median 2.6%) of all tagged fish known to pass each dam with the exception of Ice Harbor dam in 1991 (25%) when technical difficulties probably inflated our estimate. Reacension rates ranged from 17% at Lower Monumental dam in 1992 to 79% at Ice Harbor in 1991 (median 58%). Forty-two percent of the steelhead that fell back at one dam fell back at another. Of the steelhead that fell back at dams in the four study years, 47% were last located at spawning grounds or hatcheries. Steelhead fallback percentages were comparable to those for spring and summer chinook salmon at lower Snake River dams from 1991-1993 which ranged from 1.7 to 3.8% (median 1.9%) (Bjornn et al.1998).

The seasonal timing of migration at dams was consistent between study years with the majority (90+%) of steelhead passing Snake River dams in the fall of the year they were tagged; few fish each year migrated past the dams in the summer or the spring of the following year. Steelhead destined for the upper Snake River and its tributaries generally passed the Asotin, WA, receiver in the fall before wintering over. By

comparison, steelhead destined for the Clearwater River drainage passed the Clearwater receiver site at a proportionally higher rate in the spring after wintering over in the Lower Granite Reservoir, the confluence area of the Snake and Clearwater rivers or the lower reaches of the Snake and Clearwater rivers. As steelhead progressed further upriver, an increasingly larger proportion paused to winter over. About half the steelhead that reached the lower Salmon River receiver passed the site in the fall and half passed in the spring. Proportions of steelhead of hatchery and wild origin to arrive at receiver sites in summer, fall and spring were nearly identical.

Of those steelhead with known overwintering locations, 58.6% of the summer-released fish and 71.1% of those released in fall wintered over upstream of Lower Granite Dam. As reported previously, 90% of steelhead with transmitters passed Lower Granite Dam before 31 December, and it is reasonable to assume they wintered over upstream from the dam. The difference between 90% and 59 or 71% was due in part to the relatively large number of steelhead that wintered over in Lower Granite reservoir, including the Snake-Clearwater confluence, and did not survive the winter to resume their migration in the spring past the next upstream receiver site (many were harvested). The percent that overwintered upstream from Lower Granite Dam for the four years combined was also lower because a smaller percentage of the steelhead released at John Day Dam in 1993 wintered over upstream of Lower Granite Dam (56.3% of summer and 57.0% of fall released steelhead). Some of those steelhead were destined for tributaries other than the Snake River.

In the four study years, between 3.3 and 8.6% of the steelhead released with transmitters each year were never located after release. Of the steelhead released in the vicinity of Ice Harbor Dam in 1991, 1992 and 1994, between 10.4 and 12.5% were last located in the Columbia River or its tributaries. Understandably, in 1993 when fish were tagged and released at John Day Dam, a higher proportion (52%) of the steelhead were last located in the Columbia River and its tributaries. Of the 884 steelhead released at John Day Dam, 151 (17%) were recorded at least temporarily in the Deschutes River downstream from John Day Dam. Of these fish, 81 had telemetry records of a full migration history indicating they had returned to a natal stream or hatchery with 57 of those returning to the Snake River drainage. The indication was that 38 to 42.5% of the steelhead last recorded in the Deschutes River might have been of Snake River origin.

The percentage of tagged steelhead to pass Lower Granite Dam was 58 and 61% for summer- and fall-released steelhead in 1991 and 1992, 38% in 1993 when fish were tagged at John Day Dam and 66% in 1994 when steelhead were tagged and released only in the fall near Ice Harbor Dam. Once steelhead passed Lower Granite Dam, their dispersal into tributaries was consistent over the four study years. Based on last telemetry records and recaptures by anglers and at weirs or hatcheries, between 19 and 33% of all tagged steelhead to pass Lower Granite Dam were last located in the Lower Granite Reservoir, 32 to 38% in the Clearwater River basin, 15 to 19% in the Snake River upstream from Lewiston, 3 to 7% in the Grande Ronde River basin, 18 to 20% in the Salmon River basin and 0 to 1% in the Imnaha River drainage.

Rates of tag recapture ranged from 26 to 38% during the study with the majority (68%) of the 947 returned tags being returned from fisheries. Returns from hatcheries and traps contributed 18 and 5% of all recaptures and 5% were transmitters that we suspected were regurgitated and later found.

The percent of tags recaptured from the Columbia River below the mouth of the Snake River ranged from 8.3 to 15.9% for the years steelhead were released near Ice

Harbor Dam; 41% of all recaptured tags in 1993 originated from this reach. Between 0.7 and 6.0% of tags recaptured in all study years were from the Columbia River upstream of the mouth of the Snake River. Recaptures from the Snake River from its mouth to Hell's Canyon Dam ranged from 19.5 to 42% of all recaptures in all years, 20 to 41% came from the Clearwater River drainage and 7.8 to 23% came from the Salmon River drainage in all years. These proportions were not dissimilar to proportions of tagged steelhead last located in these reaches.

Reach survival estimates were high (mean ~ 95%) for all years with the exception of steelhead released in the summer of 1992. Only 84% of the steelhead released at Charbonneau Park in summer 1992 successfully migrated from the release site past Lower Monumental Dam. There was also a high rate of fallback at Ice Harbor dam associated with this release; we speculate many of the steelhead released in the summer of 1992 at Charbonneau Park were destined for the Columbia River drainage and would not be expected to ascend the Snake River.

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