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Migration Characteristics and Hatchery Returns of Winter Steelhead Volitionally Released from Cole Rivers Hatchery, Oregon

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Abstract.—Juvenile winter steelhead *Oncorhynchus mykiss* from four brood years were reared at Cole Rivers Hatchery on the Rogue River and were released from raceways each year either by volitional migration from 1 April to 16 June or by forced eviction during 21–26 April. The date of maximum volitional migration was 4 May ± 7 d. Recapture of "half-pounders" (the small immature steelhead that enter the river in the summer and fall, after 2–6 months at sea) was not significantly different between the two release groups, but fewer adults returned to the hatchery from groups that had been volitionally released than from groups that had been forced from the raceways. No significant difference in average adult size or life history composition at each return age was found between the two groups.

Various biological and physical factors, including species, age, growth rate, physiological development, genetic characteristics, photoperiod, and water temperature, influence the precise time that individual salmonid smolts migrate to the ocean. In many hatcheries, salmonids have been permitted to migrate volitionally from raceways to account for these diverse factors. Volitional release has been claimed to provide greater survival of juvenile salmonids to adulthood than does the common practice of forcefully evicting fish of a certain size from hatchery raceways at a predetermined time (Brannon et al. 1982). Volitional release methods may shorten the average period of riverine residence. Extended delay in the river is thought to reduce survival rates to adulthood.

There have been few tests to evaluate the effectiveness of volitional releases. Wagner (1968) found no difference in survival between steelhead *Oncorhynchus mykiss* from volitional and forced releases on the Alsea River, Oregon. Gowan and McNeil (1984) found that the volitional release of coho salmon *O. kisutch* resulted in lower survival than did forced releases. Appleby and Seidel (1990) reported that coho salmon that were allowed to migrate volitionally showed comparable overall survival to those that were force-released.

This article describes the migratory pattern of steelhead during 4 years of volitional releases at Cole Rivers Hatchery. Capture rates of "half-pounders" (as defined in Everest 1973: the small immature steelhead that enter the river in the summer and fall, after 2–6 months at sea) were determined from seining in the lower Rogue River, and return rates and life history composition for adults returning to the Cole Rivers Hatchery also were determined. These values were compared among steelhead that were volitionally released and those that were forced from raceway ponds in late April.

Methods

Winter steelhead that made up the 1977–1980 broods returned to Cole Rivers Hatchery (located on the Rogue River, at river kilometer 254, as measured from the river's mouth) from February through May. Adults were spawned from March through May, and eggs, fry, and fingerlings were reared for 2 years in a manner similar to that described by Ewing et al. (1984). Juvenile steelhead were graded by size with a Morton adjustable grader (Morton 1956) two or three times during their hatchery rearing period. After the last grading during the final summer of rearing, two groups were established, either by weighing equal numbers of fish from each of 2–3 ponds or by selecting two ponds with fish of approximately equal size and number. One group was designated for volitional release and the other was designated for forced release, and the fish were marked with distinct and complementary marks by clipping one or more fins and one maxillary bone 6–8 months before release. Complementary fin clips were used to pre-

TABLE 1.—Characteristics of winter steelhead when they were subjected to volitional or forced releases, 1979–1982. Values are weighted means (±95% confidence limits) for samples taken throughout the period of volitional release.

Release year and group	Number released	Fin mark[a]	Mean fork length (cm)	Mean weight (g)	Condition factor[b]	Number sampled
1979						
Volitional	16,152	LvRm	21.2 ± 0.5	94.1 ± 7.5	1.00 ± 0.01	28
Forced	19,386	RvLm	20.6 ± 0.7	89.4 ± 8.0	1.01 ± 0.02	110
1980						
Volitional	11,022	AdLpLm	22.7 ± 0.6	111.1 ± 10.2	0.93 ± 0.02	30
Forced	16,922	AdRpRm	21.7 ± 0.4	104.3 ± 6.0	1.00 ± 0.01	92
1981						
Volitional	7,866	LvRm	21.7 ± 0.2	106.0 ± 2.8	1.01 ± 0.01	91
Forced	13,433	RvLm	22.4 ± 0.4	111.8 ± 5.6	0.98 ± 0.01	98
1982						
Volitional	12,376	AdRpRm	22.9 ± 0.6	115.8 ± 10.3	0.99 ± 0.02	92
Forced	22,631	AdLpRm	22.3 ± 0.6	114.1 ± 9.7	0.95 ± 0.02	95
Average, all years						
Volitional			22.1 ± 0.2	107.0 ± 7.7	0.98 ± 0.02	
Forced			21.8 ± 0.5	104.9 ± 7.3	0.99 ± 0.02	

[a] Fin mark abbreviations: Ad = adipose; Lv = left ventral; Rv = right ventral; Lp = left pectoral; Rp = right pectoral; Lm = left maxillary; Rm = right maxillary.

[b] Condition factor = 100 × (weight, g)/(fork length, cm)^3.

vent differential mortalities from fin loss (Wales 1947; Shetter 1951). One to two weeks before the beginning of the volitional releases, precocious males and fish measuring less than 16 cm in fork length (projected to be less than 18 cm in late April) were removed by hand-sorting to eliminate fish with little expectancy of smolting (Buchanan 1980; Ward and Slaney 1990). (All fish lengths are given in fork lengths.)

Steelhead to be subjected to forced release were reared in 30.5- × 6.1- × 1.2-m raceways. Flow into the raceway was approximately 40–50 L/s, and water current was undetectable with a Gurley flow meter. Fish were released in a 1–2-h daylight period; first they were forced from the raceway into a 1-m-wide smolt release channel, and then they were forced from the release channel into the river. Mean sizes at release were about 21–22 cm (Table 1).

Steelhead to be subjected to volitional releases were reared under similar conditions, except that, on 1 April of each year, a screen at the downstream end of the raceway was modified to create an opening 0.9 m wide and 0.1 m deep at the surface of the water. Fish were free to move through this opening into a 3.7- × 1.7- × 1.2-m space behind the raceway screens. A plywood board with a hole 0.1 m in diameter was placed just below the water surface in one of two screened overflow outlets. Fish swam through the hole and onto a fiberglass-coated plywood trough with a partially screened bottom, which removed most of the water. The fish passed into a perforated aluminum tube, which removed most of the remaining water. They then passed into a Plexiglas tube and slid past an infrared counting device (Ewing et al. 1983) into a 6.1- × 1.7- × 0.5-m trapping area located in the adjacent raceway. Counting was done both by the infrared counting device and visually as the fish were released from the trap into a main drainage conduit leading to the river. Volitional movement from the raceway was permitted from 1 April to 16 June. Smolting characteristics for both migrant and nonmigrant fish, which were sampled throughout the release period, were previously described (Ewing et al. 1984).

After 16 June, when migration had decreased to minimal, the nonmigrant steelhead were stocked in a local lake so that they would not contribute to adult returns.

Marked fish from the release groups were captured either as half-pounders (Everest 1973) or as adults returning to the hatchery. Half-pounders were captured from early July through late October at river km 13 on the Rogue River. A sinking beach seine with square mesh openings that varied from 3.5 cm (in the center of the net) to 7.6 cm (at the wings) was used to capture the fish. Seining effort was standardized at 3 d/week and 15 sets/d during the sampling period.

Adults returning to the hatchery were captured and segregated by sex and fin mark. Adults from

TABLE 2.—Characteristics of various life history types of Rogue River winter steelhead reared at Cole Rivers Hatchery.

Life history type	Adult age	Description[a]
2/H+	3	2 years in fresh water, migration to sea, half-pounder migration, return as adult to fresh water for spawning after 1+ years at sea
2/1+	3	2 years in fresh water, migration to sea, return as adult to fresh water for spawning after 1+ years at sea
2/H1+	4	2 years in fresh water, migration to sea, half-pounder migration, return as adult to fresh water for spawning after 2+ years at sea
2/2+	4	2 years in fresh water, migration to sea, return as adult to fresh water for spawning after 2+ years at sea
2/HS+	4	2 years in fresh water, migration to sea, half-pounder migration, return as adult to fresh water for spawning after 1+ years at sea, migration to the sea after spawning and return to fresh water the following winter for second spawning
2/1S+	4	2 years in fresh water, migration to sea, return as adult to fresh water for spawning after 1+ years at sea, migration to the sea after spawning and return to fresh water the following winter for second spawning
3/H+	4	3 years in fresh water, migration to sea, half-pounder migration, return as adult to fresh water for spawning after 1+ years at sea
3/1+	4	3 years in fresh water, migration to sea, return as adult to fresh water for spawning after 1+ years at sea
3/2+	5	3 years in fresh water, migration to sea, return as adult to fresh water for spawning after 2+ years at sea
2/HSS+	5	2 years in fresh water, migration to sea, half-pounder migration, return as adult to freshwater for spawning after 1+ years at sea, migration to the sea after spawning and return to fresh water the following winter for second spawning, migration to the sea and return the following winter for third spawning
3/HS+	5	3 years in fresh water, migration to sea, half-pounder migration, return as adult to fresh water for spawning after 1+ years at sea, migration to the sea after spawning and return the following winter for second spawning

[a] *Half-pounder migration* entails the migration of juveniles to the sea in April and May, their return to the river as immature half-pounders from July through October (after 2–6 months at sea), and a return to the sea about 6 months later. For years at sea, a plus sign denotes a possible 1–12 months in addition to the number of years given.

both experimental and control groups were measured for fork length, and scale samples were taken from them. At least two representative scales from each fish were examined under a microscope, and the life history was determined according to criteria developed in an earlier study (Everest 1973).

Eleven life history types for hatchery-reared winter steelhead were identified (Table 2). The most abundant life history type was that designated 2/H+. This type undergoes the half-pounder migration described for summer steelhead by Everest (1973). Juveniles leave the river in April and May, spend 2–6 months at sea, and return to the river from July through October as immature half-pounders, which are approximately 30–40 cm long. These fish remain in the river for 6 months (on average) before returning to sea, where they remain for a year until they return in their second winter at sea on a spawning migration.

All statistical analyses were performed at the 95% level of confidence. Comparisons of capture rates of half-pounders at river km 13 and comparisons of returns of adults to the hatchery were accomplished with binomial distribution tests (Snedecor and Cochran 1980). Lengths were compared with analysis of variance and Student's *t*-tests.

Results

The average date of maximum migration of winter steelhead undergoing volitional release was 4 May ± 7 d (± SE) (Table 3). The average percentage of migration from the raceways was 67 ± 10% (± SE). Percent migration varied from 55% (in 1980) to 80% (in 1979). Migration usually took place as the water temperature of the raceway rose above 6°C (Figure 1), but average water temperature at maximum migration was 9.3 ± 1.9°C (± SE).

Maximum out-migration occurred during the first quarter of the lunar cycle in 3 of the 4 years (Table 3). These results may indicate a relationship between migration timing and the lunar cycle—but not the new-moon quarter, as suggested by Grau (1982). From our casual observations, we noticed that rainfall did not seem to stimulate migration.

Returns of volitionally released steelhead to Cole Rivers Hatchery were less than those of forced-release fish for 3 of the 4 years of tests (Table 4), but differences were usually not significant at the 95% level. However, for the 4 years of the experiment, the overall average percent return of the volitional-release fish to the hatchery was significantly smaller ($P \leq 0.05$) than that of forced-release fish. This relationship was dominated by age-3 fish (those that remained at sea for more than 1 year; see Table 2). Average percent returns of age-4 and age-5 fish were not significantly different ($P > 0.05$) between groups.

TABLE 3.—Migration characteristics for winter steelhead undergoing volitional release from Cole Rivers Hatchery.

Release year	Date of maximum migration	Temperature at maximum migration (°C)	Lunar phase	Total migration (%)
1979	7 May	7.9	1st quarter	80
1980	4 May	9.4	1st quarter	55
1981	9 May	11.9	1st quarter	67
1982	24 Apr	7.8	New moon	65
Average ± SE, all years	4 May ± 7 d	9.3 ± 1.9		67 ± 10

Capture rates of half-pounders at river km 13 showed no significant difference ($P > 0.05$) between volitional-release and forced-release groups (Table 4), except in the case of the 1980 brood, where half-pounders from the volitional-release group were captured at twice the rate as those from the forced-release group. Overall average capture rates for the 4 years were the same (0.18%) for both groups.

Life history composition of the forced-release groups was not statistically different ($P > 0.05$) from year to year for age-3 fish (Table 5). More variability was observed in the age-3 fish from the volitional-release groups, where the most common life history type, 2/H+, constituted from 48 to 88% of the total age-3 fish. Composition of the age-4 group was more variable, but differences in percentages were exaggerated by the low numbers of fish returning. Mean lengths of adults of various life history types (Table 5) were not significantly different ($P > 0.05$) between release methods, as measured by analysis of variance.

Discussion

The basis for these experiments is the assumption that the release timing that provides maximum survival to adulthood is best determined by the migration behavior displayed by the fish. Indeed, Brannon et al. (1982) attribute their successful zero-age coho salmon production to volitional releases but provide no evidence to support this claim.

Evidence is accumulating to support the opposite conclusion: volitional releases may result in fewer returns of adults. In one of the earliest studies of this type, Wagner (1968) allowed Alsea River steelhead to emigrate volitionally from Alsea Hatchery, Oregon, from early February to mid-May. Those remaining in the pond after mid-May were then forced out into the river. Returns of these adults to the hatchery were compared with returns of comparably sized steelhead that were forced from the hatchery in mid-April. Although Wagner did not statistically compare combined returns from groups released by the two methods, he provided data necessary to show that, for 3 years of releases, returns from forced releases (6.6%) were significantly greater ($P \leq 0.05$) than those from volitional releases (5.7%). The percent survival of the volitional-release groups was only 86% of that of the forced-release groups, a ratio similar to that reported here.

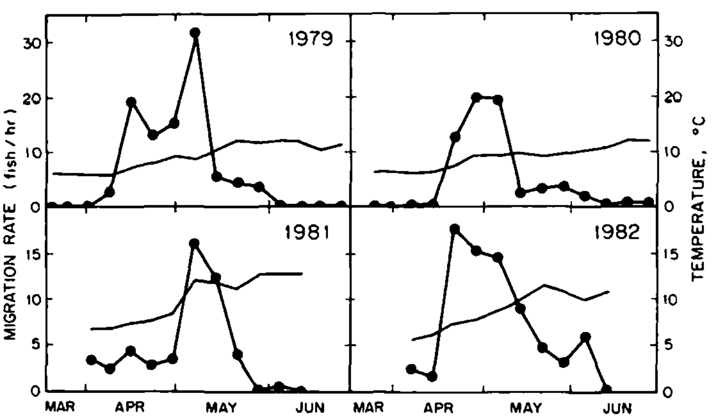

FIGURE 1.—Rates at which winter steelhead migrated volitionally from hatchery raceways, 1979–1982. Rates are averages over weekly periods. Water temperatures are shown by the solid lines without data points.

TABLE 4.—Percentage of volitional-release and forced-release winter steelhead that were captured as "half-pounders" by seining at river km 13 and that returned as adults to Cole Rivers Hatchery. (Half-pounders are the small immature steelhead that enter the river in the summer and fall, after 2–6 months at sea.) Numbers of fish are given in parentheses. An asterisk denotes a value that is significantly different from that of the control group (forced release) at the 95% confidence level. Total releases (1977–1980 broods) were 47,416 fish for volitional release and 72,372 fish for forced release.

Group	Half-pounders	Adults				*Total,* adults and half-pounders
		Age-3	Age-4	Age-5	Total	
1977 brood						
Volitional	0.07 (12)	0.10 (16)	0.07 (11)	0.01 (1)	0.17 (28)	0.25 (40)
Forced	0.06 (11)	0.13 (26)	0.11 (22)	0 (0)	0.25 (48)	0.30 (59)
1978 brood						
Volitional	0.28 (31)	0.54 (59)	0.12 (13)	0 (0)	0.65 (72)	0.93 (103)
Forced	0.37 (63)	0.61 (103)	0.15 (25)	0 (0)	0.76 (128)	1.13 (191)
1979 brood						
Volitional	0.18 (14)	0.84 (66)	0.52 (41)	0.01 (1)	1.37 (108)	1.55 (122)
Forced	0.24 (32)	1.06 (143)	0.45 (61)	0.01 (1)	1.53 (205)	1.76 (237)
1980 brood						
Volitional	0.22* (27)	1.26 (156)	0.23* (28)	0 (0)	1.49 (184)	1.70 (211)
Forced	0.11 (25)	1.29 (292)	0.12 (27)	0 (0)	1.41 (319)	1.52 (344)
Average, all broods						
Volitional	0.18 (84)	0.63* (297)	0.20 (93)	0.004 (2)	0.83* (392)	1.00* (476)
Forced	0.18 (131)	0.78 (564)	0.19 (135)	0.001 (1)	0.97 (700)	1.15 (831)

There are some important differences between the present study and that of Wagner (1968), so the ratios of returns from volitional-release groups and returns from forced-release groups cannot be strictly compared between the two studies. Wagner released into the river the fish of the volitional-release group that remained after 16 May, whereas we trucked our remaining fish to a nearby lake. If we recalculate our average percent return to Cole Rivers Hatchery based on the total number of fish originally in the volitional-release groups, the average percent return over the 4 years is only 0.55% for the volitional-release groups but is 0.97% for the forced-release groups. The ratio of returns of volitional and forced releases of steelhead at Cole Rivers Hatchery is then 0.57, comparable to that observed by Gowan and McNeil (1984) for coho salmon.

One of the few studies that have shown greater survival for volitionally released salmonids is that of Appleby and Seidel (1990). They found that, of the 1983 broods of coho salmon from Grays River and Kalama Falls hatcheries, those from volitional releases had higher survival than did those from forced releases. However, of the 1984 and 1985 broods of coho salmon from both hatcheries, forced-release groups had better survival than did volitionally released groups, although these differences were only significant for the 1984 brood from Kalama Falls Hatchery ($P \leq 0.05$). Overall, comparable survival was observed with both groups.

An important consideration in volitional-release studies is whether the movement from the raceways represents a true seaward migration or a random movement of the population. Several studies have indicated that fish moving from raceways show physiological characteristics of smolting and seaward-migrating fish. Kerstetter and Keeler (1976) found that steelhead volitionally migrating from hatchery ponds had elevated levels of gill Na^+,K^+-ATPase. Zaugg and Wagner (1973) and Bjornn et al. (1978) found similar results in studies of seaward migration in steelhead. Ewing et al. (1984) reported earlier for the present study that measurements of silvering, condition factor, gill Na^+,K^+-ATPase activity, and plasma thyroxine (T_4) concentration in the migrant fish from the volitional-release group were suggestive of smolting. Thus, it seems likely that the movement from the raceways represents a true migration.

Because smaller volitionally released fish have lower migration rates, smaller steelhead were removed from the groups of juveniles used in the present study to avoid difficulty in interpreting the return data. For hatchery-reared summer steelhead in Oregon, Buchanan (1980) observed lower migration rates for juveniles that were smaller than the migration threshold size of 16–17 cm suggested by Wagner et al. (1963). In another study, Ward

TABLE 5.—Life history composition (%) and fork lengths (FL) for various life history types of winter steelhead returning to Cole Rivers Hatchery from volitional-release and forced-release groups. Values for life history composition are percentages of each age-class. Life history types are as described in Table 2. Length values are means in centimeters ± 95% confidence limits. Numbers of fish (*N*) are given in parentheses.

Age and life history type	Statistic	1977 brood		1978 brood		1979 brood		1980 brood	
		Volitional	Forced	Volitional	Forced	Volitional	Forced	Volitional	Forced
Age 3									
2/H+	%	87.5	61.5	47.5	66.0	77.3	66.7	78.6	75.0
	FL	58.3±2.3	55.7±2.2	57.7±1.7	59.3±1.1	59.1±1.0	58.5±0.8	61.5±0.6	61.0±0.5
	N	(14)	(16)	(28)	(68)	(51)	(94)	(121)	(216)
2/1+	%	12.5	38.5	52.5	34.0	22.7	33.3	21.4	25.0
	FL	64.4±4.2	65.9±1.9	65.7±1.1	65.0±1.1	66.2±1.7	66.0±1.0	67.0±1.3	67.7±0.9
	N	(2)	(10)	(31)	(35)	(15)	(47)	(33)	(72)
Age 4									
2/H1+	%	72.7	90.9	46.2	32.0	85.4	72.1	65.5	57.7
	FL	67.4±2.6	68.1±1.7	70.8±1.7	68.4±3.2	72.1±1.5	71.1±1.3	70.7±1.5	71.0±1.7
	N	(8)	(20)	(6)	(8)	(35)	(44)	(19)	(15)
2/2+	%	9.1	4.5	30.8	16.0	2.4	4.9	6.9	3.8
	FL	65.3	66.7	71.6±3.6	72.6±3.6	73.6	74.7±14.8	72.4±22.2	71.8
	N	(1)	(1)	(4)	(4)	(1)	(3)	(2)	(1)
2/HS+	%	9.1	0	23.1	44.0	9.8	13.1	6.9	23.1
	FL	63.8		66.6±6.6	64.8±3.4	65.0±3.7	64.8±2.6	69.0±6.7	66.1±3.9
	N	(1)	(0)	(3)	(11)	(4)	(8)	(2)	(6)
2/1S+	%	0	0	0	4.0	0	1.6	6.9	0
	FL				67.5		73.8	69.0±9.5	
	N	(0)	(0)	(0)	(1)	(0)	(1)	(2)	(0)
3/H+	%	0	0	0	4.0	0	1.6	0	3.8
	FL				54.8		58.3		68.7
	N	(0)	(0)	(0)	(1)	(0)	(1)	(0)	(1)
3/1+	%	9.1	4.5	0	0	2.4	6.6	13.8	11.5
	FL	66.9	64.8			70.7	67.0±3.1	69.2±6.1	66.3±2.2
	N	(1)	(1)	(0)	(0)	(1)	(4)	(4)	(3)
Age 5									
3/2+	%	0	0	0	0	0	100	0	0
	FL						81.7		
	N	(0)	(0)	(0)	(0)	(0)	(1)	(0)	(0)
2/HSS+	%	100	0	0	0	0	0	0	0
	FL	68.2							
	N	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
3/HS+	%	0	0	0	0	100	0	0	0
	FL					68.1			
	N	(0)	(0)	(0)	(0)	(1)	(0)	(0)	(0)

and Slaney (1990) reported lower migration rates for smaller juvenile winter steelhead released in a stream in British Columbia. Previously reported data from the present study also showed lower migration rates for smaller volitionally released fish (Ewing et al. 1984).

Timing of releases is an important consideration for the liberations of hatchery-reared salmonids. Juvenile salmonids may display active downstream migration behavior over a wide time period after the onset of parr–smolt transformation and may emigrate successfully to the sea. However, migration, estuarine, and ocean conditions that interact to produce maximum rates of survival to adulthood may exist for a relatively small portion of the migration period. Coho salmon broods released in June may have a higher rate of survival to adulthood than do fish released in May (Bilton et al. 1982), even though strong migration behavior is exhibited at earlier times (Appleby and Seidel 1990). Everest (1973) found that wild Rogue River summer steelhead migrated from a small tributary in a relatively short time period in April and May, and that migration peaked at about 1 May. Everest also observed that the size of smolts and timing of migration appeared to be similar among these wild summer steelhead and other races of summer and winter steelhead in Oregon.

Wagner (1974) showed that photoperiod is the main environmental factor controlling the onset of parr–smolt transformation in steelhead, as evidenced by migratory behavior, and that temperature can influence the duration of the migration period. Steelhead restricted from migrating during this period may revert to a nonmigratory state (Wagner 1968).

In the present study, the release time for the forced-release groups (21–26 April) closely approximated the time at which peak migration rates occurred in the volitional-release groups (mean ± SE, 4 May ± 7 d). Therefore, there may have been little difference between release practices in the time that most smolts entered the ocean. As indicated above, coho salmon released after the time of maximum migration can have a higher survival rate. If steelhead behave similarly, the forced-release method may be advantageous. Smolt migration characteristics and the release time that produces maximum survival rates vary between years, and as a result volitional-release fish may have greater returns in some years. The significantly greater ($P \leq 0.05$) capture rates of half-pounders and the significantly greater returns of age-4 adults produced by the volitional-release group released in 1982 (1980 brood) may be attributable to these factors. In 1982, the date of maximum smolt migration for the volitional-release group was 10 d earlier than in any of the other 3 years of releases.

The similarity of life history composition and size at return for each life history type for adults returning from the two release methods may also indicate that smolts released by the two procedures entered the ocean at approximately the same time. For coho salmon (Bilton 1978) and chinook salmon *O. tshawytscha* (Hankin 1990), release time affects both the proportion of fish maturing at each age and the size of adults at each age. In the case of wild juvenile winter steelhead from the Rogue River, those that enter the ocean at younger ages return at greater rates as half-pounders than do those that enter the ocean at older ages (Tom Satterthwaite, Oregon Department of Fish and Wildlife, personal communication). However, the influence of release time and ocean entry time on life history frequencies for adult steelhead and size at maturity for each life history type is not well understood and needs further investigation.

Volitional release methods used in the present experiment may not have permitted emigration of all fish capable of migrating. The evidence supporting this conclusion is the relatively small differences in percent returns for volitional and forced releases. Equal return rates would be expected if similar proportions of those fish that reached the river, either volitionally or by forced release, migrated to the sea and were subjected equally to factors limiting survival. Although more study is needed, it is reasonable to suspect that hatchery conditions or the volitional release methods used in this study suppress the migratory tendency in some way and that forcing the fish into the river restimulates this migratory urge. Radiotelemetry should be used in future studies to evaluate residual rates and behavior differences related to release method.

Mortality of juveniles in fresh water may have substantially affected the return rates observed in the present study. Hallock et al. (1961) noted that an important source of mortality for juvenile steelhead before they reach the sea is the catching of these juveniles as legal-sized rainbow trout (nonanadromous *Oncorhynchus mykiss*) by recreational anglers after the spring opening of trout season. An evaluation of creel data collected from the McKenzie River in Oregon in 1973 revealed that 22–41% of the 2-year-old steelhead smolts released in the river were caught in the spring trout fishery (D. Buchanan, Oregon Department of Fish and Wildlife, personal communication). In the present study, those juveniles that remained in the river beyond the opening of trout season in late May were subject to the trout sport fishery. Unpublished data from the Oregon Department of Fish and Wildlife indicate that over 80% of the trout catch on the opening weekend of trout season in the 10–20 km downstream of the hatchery may be juvenile steelhead released about 1 month earlier. If steelhead released volitionally continue their downstream migration without delay while a substantial portion of fish from the forced-release groups delay migration or become residual, as suggested by Wagner (1968), juvenile angling mortality should be greatest for fish that were force-released. Insufficient creel data was collected during the present study to reject or validate this hypothesis.

Juvenile mortality resulting from predation in fresh water also may have substantially impacted return rates. The slightly lower return of steelhead released volitionally may result from depensatory predation, as postulated by Neave (1953). Because fewer steelhead from volitional releases are migrating at any given time, they may not saturate the predators along their migration route in the same fashion as steelhead from forced releases. At present, however, we do not know the major source of mortality for juvenile steelhead as they make their way to the sea or when they are at sea.

Until we have a better understanding of the mechanisms limiting survival, we must rely on empirical studies such as the present one. From this study, we conclude that volitional release of steelhead does not improve their survival.

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