PARR-SMOLT TRANSFORMATION AND SEAWARD MIGRATION OF WILD AND HATCHERY STEELHEAD TROUT IN IDAHO

by

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A Final Report

from

Project F-49-R

Salmon and Steelhead Investigations

A

FEDERAL AID TO FISH AND WILDLIFE RESTORATION PROJECT

Administered by the

Idaho Department of Fish and Game

February 1978

ACKNOWLEDGMENTS

This project was supported by the Idaho Department of Fish and Game, U. S. Fish and Wildlife Service and University of Idaho through the Idaho Cooperative Fishery Research Unit.

We thank Steve Mate, Robert Quidor, Melvin Reingold and Dean Myers of the Department of Fish and Game for their assistance. Howard Raymond of the National Marine Fisheries Service provided data on smolts trapped at Riggins and the Snake River dams.

The Idaho Cooperative Fishery Research Unit is supported by the U. S. Fish and Wildlife Service, University of Idaho, and the Idaho Department of Fish and Game.

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TABLE F CONTENTS

ABSTRACT

We studied the transformation from parr to smolt and factors related to the transformation of wild and hatchery summer steelhead trout *(Salmo gairdneri)* indigenous to the Snake River drainage in 1973 and 1974. Changes in appearance, coefficient of condition, NaK-ATPase activity, saltwater tolerance, and migratory behavior were used as indexes of the transformation. For hatchery fish we evaluated the effects of date of release, length and age at release, rearing in 15 C versus 10 C water and cold water conditioning on the transformation and seaward migration.

Parr-smolt transformation in wild and hatchery summer steelhead trout was size dependent and seasonal in occurrence. Summer steelhead trout must be at least 140 - 160 mm in length for the transformation and seaward migration to occur. The downstream migration of wild and hatchery steelhead trout occurred from April through mid-June with the peak of migration from early to mid-May. Smolts which did not migrate reverted to parr before the first of July.

Summer steelhead trout which had undergone parr-smolt transformation became silvery in appearance, had a reduced coefficient of condition, an elevation in gill NaK-ATPase activity, and migrated soon after release. Changes in appearance, coefficient of condition, and NaK-ATPase activity preceded the onset of seaward migration but the ability to survive in saltwater was not fully developed in the fish we tested at the time of release.

Hatchery steelhead trout released at the start of the normal period of seaward migration by wild fish (mid-April) migrated soon after release and in larger numbers than fish released earlier in the migration season. Late April appeared to be the optimum time of release for age I steelhead trout reared at the Hayden Creek Station and Niagara Springs Hatchery.

Steelhead trout longer than 170 mm had more pronounced and earlier changes associated with parr-smolt transformation than fish shorter than 170 mm. Large fish migrated earlier and in larger numbers than small fish.

Hatchery steelhead trout classified as smolts or intermediates at release migrated at a higher rate than fish classified as parrs. Fish classified as parrs which did migrate, did so as early as fish classified as smolts or intermediates.

The onset of smoltification occurred earlier for fish reared two years than for those reared one year in a hatchery. The two year old steelhead trout migrated more rapidly and in larger numbers than comparable one year old fish.

Steelhead trout reared in the 15 C water at Niagara Springs Hatchery had less pronounced changes in coefficient of condition and NaK-ATPase activity and probably a less complete parr-smolt transformation than fish reared in colder water. A smaller percentage of the Niagara Springs steelhead trout migrated and they did so later in the migration season than fish reared at Hayden Creek Station in cooler water.

Conditioning steelhead trout in cold water (1.7 - 8.9 C) for 2-8 weeks before release after being reared in 15 C water did not increase the number of fish migrating before June 1 or accelerate the timing of migration. Cold water conditioning seemed to delay the migration of some fish.

INTRODUCTION

The success of Idaho's hatchery programs for summer steelhead trout depends on an adequate understanding of the life history and ecological requirements of the fish. Biologists have studied the transformation from parr to smolt of winter steelhead trout stocks on the Pacific coast but little information was available on the inland stocks of summer steelhead trout that could be used in setting operational guidelines for the large hatcheries constructed in Idaho during the 1960's and 1970's. This study was initiated in 1973 to provide some of the information managers need to specify the optimum size/age of fish to release, special rearing requirements and date of release for hatchery-reared steelhead trout.

In this report, we describe the characteristics of selected stocks of summer steelhead trout from the Snake River during parr-smolt transformation and migration to the sea. Appearance, coefficient of condition, Nak-ATPase activity, saltwater tolerance, and migratory behavior were used as indexes of the transformation. We also report on the effects of date of release, length and age when released, rearing environment and cold water conditioning on the seaward migration of hatchery steelhead trout.

The transformation, or metamorphosis, of a young trout or salmon adapted for life in freshwater into a fish that can survive in the sea is a unique characteristic of anadromous salmonids. The terms "parr-smolt transformation" or "smoltification" have been used to describe the change. Steelhead trout parr are the juveniles adapted for life in freshwater and smolts are the migrating fish ready, or nearly so, for life in the marine environment.

Changes in morphology, chemical composition, physiological and biochemical functions and behavior are part of the parr-smolt transformation which occur prior to and during the seaward migration of anadromous salmonids. These changes have been the subject of several review papers (Baggerman 1960, Barrington 1961, Hoar 1965 and 1976). Such changes transform the cryptic-colored, stream dwelling fish into a silvery pelagic fish adapted to the marine environment. Salmon and trout that migrate seaward after one or more years in freshwater go through a distinctive transformation from parr to smolt. Those species that spend only a few days or months in freshwater go through a less conspicuous transformation.

Steelhead trout must reach a critical size (14-18 cm fork length for wild winter steelhead, Wagner et al. 1963) before they become smolts and migrate to the sea. Seaward migration normally peaks from mid-April to mid-May and is usually complete by early June. Parr-smolt transformation of steelhead trout seems more dependent on size than age. In nature, most steelhead migrate at two years of age or older, but in hatcheries with abundant food and suitable water temperatures fish can reach the critical size and become a smolt at one year of age.

DISTRIBUTION AND LIFE HISTORY OF STEELHEAD TROUT

Spawning stocks of steelhead trout are widely distributed along the Pacific Coast of North America. Carl et al. (1959) described their distribution as ranging from southern California to Bristol Bay, Alaska. The Columbia River and its tributaries were a major producer of steelhead trout in North America. Steelhead trout were indigenous to the Columbia River and its tributaries below natural migration barriers. In Idaho, steelhead utilized the Clearwater, Salmon, and the Snake river systems up to Augar Falls (MacCrimmon 1971), a distance of more than 977 river kilometers (607 river miles) from the ocean (Hydrology Subcommittee 1965). Falls located on the Spokane River and Pend Oreille River blocked steelhead from utilizing these watersheds in Idaho. Idaho provides an estimated 15-20% of the spawning grounds found in the Columbia River drainage and approximately 55% of the Columbia River steelhead trout.

More than 100 dams have been built or authorized in the Columbia River drainage system for power, irrigation, navigation, and water storage. To date, dams on the Columbia and Snake rivers and their tributaries have reduced the spawning and rearing habitat available to Columbia River steelhead trout runs by more than 50%. The U.S. Bureau of Reclamation completed Grand Coulee Dam in 1941. Built without fish ladders, it blocked steelhead trout and salmon from more than 1,100 river miles of main-stem and tributary spawning and rearing habitat in the upper Columbia River. The failure of fish passage facilities at Brownlee Dam on the Snake River in the late 1950's terminated steelhead trout runs to the upper Snake River drainage. Construction of Dworshak Dam by the U.S. Army Corps of Engineers in the late 1960's blocked steelhead trout from spawning grounds in the North Fork of the Clearwater River. Much of the accessible steelhead trout habitat has been degraded by increased demands on land and water resources. Even with these habitat losses the Columbia River system still contributes annually 83% of the commercial steelhead trout catch landed in the Pacific coast states (Alaska, Washington, Oregon, and California) and 35% of the sport angler caught steelhead trout in Washington, Oregon, Idaho, and California (Ebel et al. 1975).

The life history of steelhead trout is variable (Pautzke and Meigs 1940, Shapovalov and Taft 1954, Chapman 1958, Withler 1966, Everest 1973). Steelhead trout spawn in freshwater streams, where the juveniles live until they migrate to the sea to grow and mature. The young steelhead trout may migrate to sea after the first year in freshwater or delay migration up to several years. Most juvenile steelhead remain in freshwater for 2 or 3 years. The period of residence in the ocean varies with some returning to freshwater after a short stay and others remaining in saltwater for several years. Most return to spawn after 2 to 3 years. Anadromy among steelhead trout is not obligatory (Rounsefell 1958). In wild populations of steelhead trout, a small proportion of the progeny may spend their entire life in freshwater rather than follow the anadromous behavior of their parents.

There are two distinct types of steelhead trout which utilize the Columbia River system. Winter steelhead trout adults enter the Columbia River from November through April and are destined almost exclusively for the lower Columbia River (below Bonneville Dam) tributaries. Summer steelhead trout adults enter the Columbia River from April through October with peak numbers from July through early September. Most summer steelhead trout are destined for tributaries above Bonneville Dam; with the Snake River being the single most important (Fig. 1). Over 75% of the adult steelhead trout counted over McNary Dam on the Columbia River enter the Snake River (Raymond 1974).

The Snake River runs of summer steelhead trout destined for Idaho consists of two overlapping groups. An early segment (group A) is composed of smaller fish formerly produced primarily in the upper Snake, Imnaha, and Grand Ronde River drainages. The group A fish enter the Columbia River mainly during June, July and August. The group B fish enter the Columbia River mainly during August and September and are produced primarily in the Clearwater and Salmon River drainages.

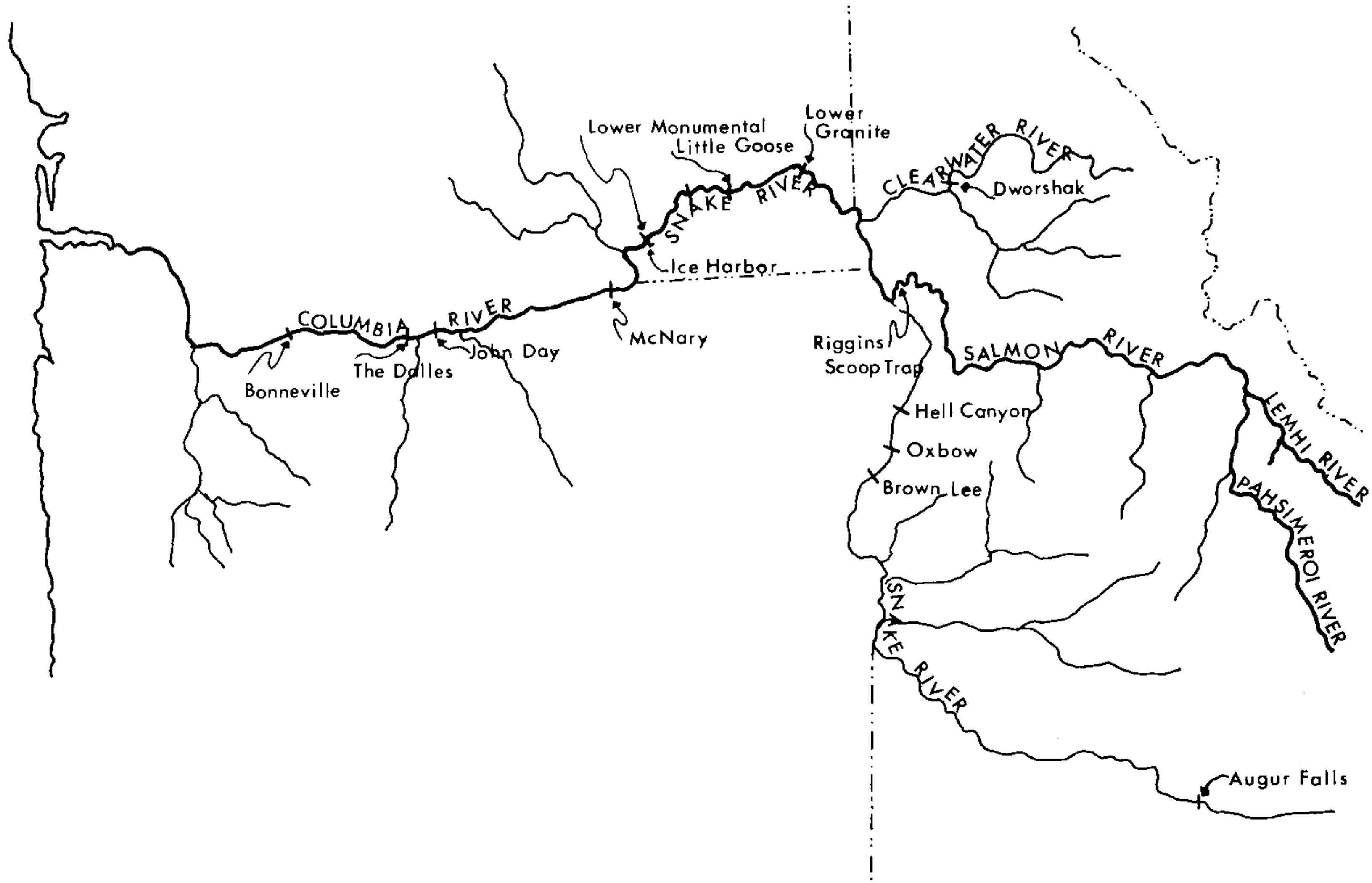

Figure 1. Map of Columbia River drainage with the location of the Lemhi River, Pahsimeroi River, and the Snake and Columbia River dams.

IDAHO SUMMER STEELHEAD TROUT HATCHERY PROGRAM

Steelhead anglers in Idaho are finding increasing proportions of hatchery-reared fish in their catches; 50% from the Salmon River and 70% from the Clearwater River in the fall of 1973 (Ortmann 1974). Artificial propagation has become an increasingly important method of supplementing and maintaining summer steelhead trout runs in Idaho streams. Hydroelectric dams in the middle Snake River and the North Fork of the Clearwater River have blocked access to large areas of spawning and rearing habitat. Hatcheries built to mitigate for the lost habitat accounted for most of the hatchery production of steelhead trout in Idaho during the early 1970's. Surplus eggs and fry from the hatcheries have been used to enhance existing runs and to develop new runs.

By 1977, Idaho had three hatcheries for the rearing of steelhead trout smolts: the Hayden Creek Research Station and the Pahsimeroi River collection facility - Niagara Springs Hatchery located in the Salmon River drainage and Dworshak National Fish Hatchery located in the Clearwater River drainage (Fig. 2).

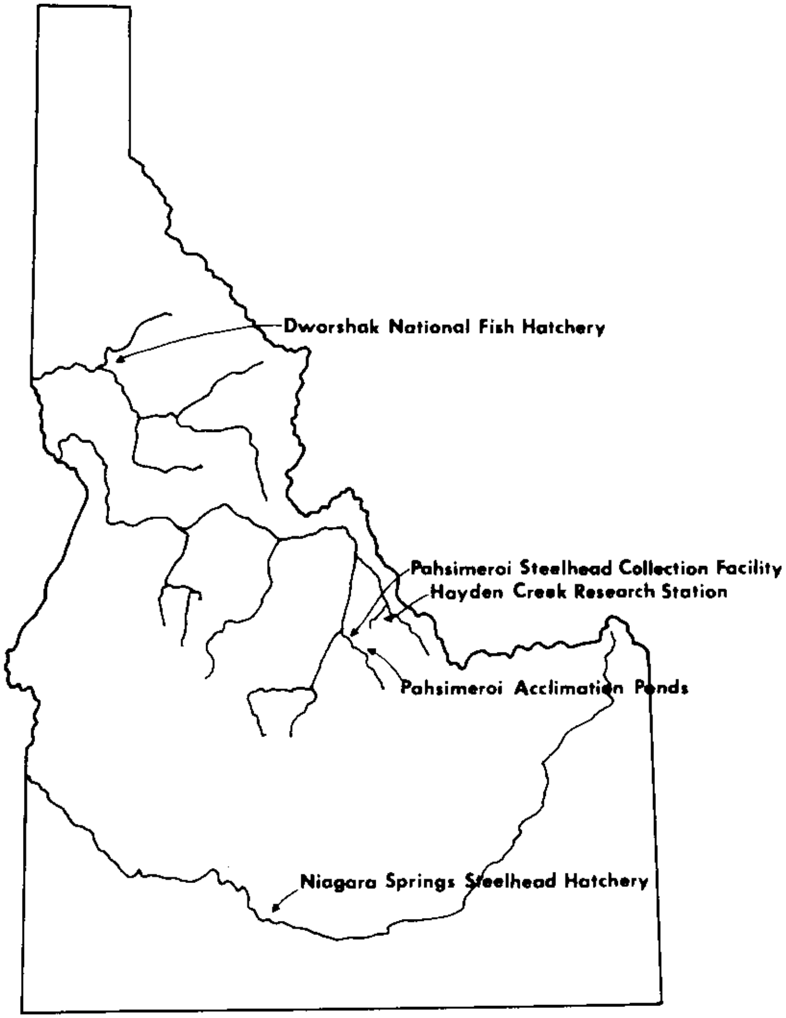

Figure 2. Location of summer steelhead trout hatcheries and facilities in Idaho.

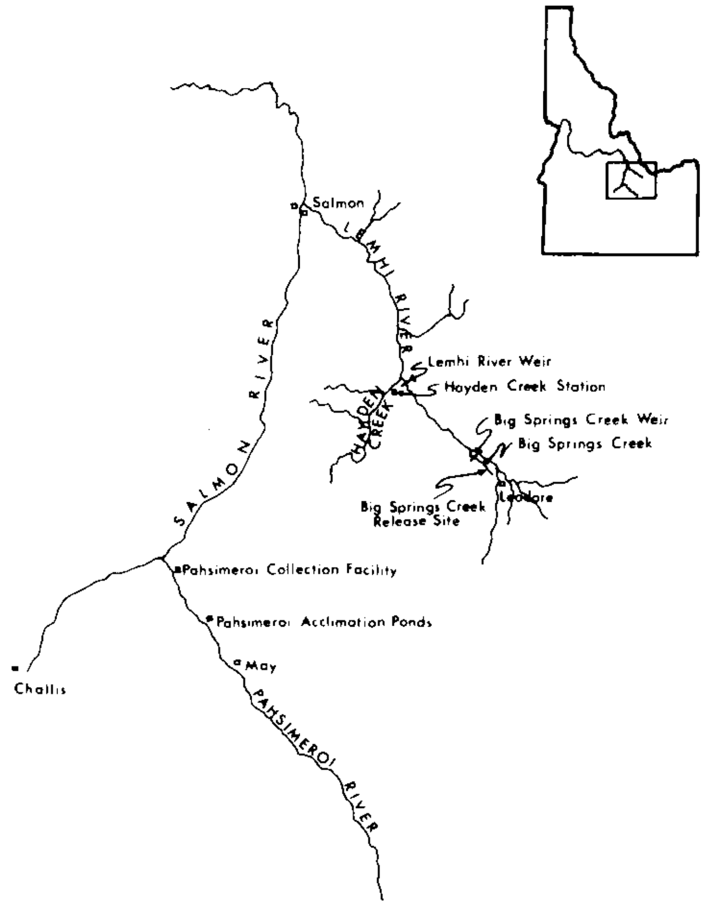

Figure 3. Map of the Lemhi River and Pahsimeroi River drainages with the location of the facilities used during the study.

STOCKS OF STEELHEAD TROUT STUDIED

Wild Steelhead Trout

We studied wild steelhead trout in Big Springs Creek and the Lemhi River and as they passed Snake and Columbia Rivers dams. In this report, we classify a steelhead trout in Big Springs Creek or the Lemhi River as "wild" whether they resulted from natural spawning or from hatchery fry released into the streams. At the dams, wild steelhead trout were smolts of unknown origin without deformity of the fins. Most hatchery-reared steelhead trout have a deformity of the dorsal fin.

Big Springs Creek and the Lemhi River originally contained an indigenous run of steelhead trout, but the abundance declined because hydroelectric and irrigation diversions blocked access to the river. Idaho Department of Fish and Game personnel began reintroducing steelhead trout in 1962 with annual releases of fry into Big Springs Creek (Bjornn 1966). Most, if not all, of the wild steelhead trout smolts migrating from Big Springs Creek and the Lemhi River in 1973 were of Clearwater River stock released into the stream as swim-up fry in August of 1971 (Bjornn 1972). The smolts from Big Springs Creek and the Lemhi River in 1974 were of Snake River stock (eggs collected at the Pahsimeroi River facility) released as swim-up fry in June of 1972 (Bjornn 1973).

Big Springs Creek and the upper Lemhi River contained resident rainbow trout (*Salmo gairdneri*) prior to reintroduction of steelhead trout. The resident trout were residual offspring of steelhead trout formerly present in the Lemhi River and/or offspring of hatchery reared rainbow trout released into the streams prior to 1962. We could not distinguish between resident rainbow and steelhead trout parr, so we used the term rainbow-steelhead when referring to parr of unknown origin.

Hatchery Steelhead Trout

We classify steelhead trout as "hatchery" fish when they are reared in the hatchery up to the smolt stage and then released for migration to the ocean. We studied steelhead trout produced at Niagara Springs Hatchery, Niagara Springs - Pahsimeroi Ponds, and the Hayden Creek Research Station.

Hayden Creek Research Station

The Hayden Creek Research Station constructed adjacent to Hayden Creek is located approximately 4.8 river kilometers (3 river miles) upstream from its confluence with the Lemhi River at river kilometer 48.8 (river mile 30.3) (Fig. 3). Hayden Creek Station is located 1294.4 river kilometers (804 river miles) from the Pacific Ocean (Hydrology Subcommittee 1965). Steelhead smolts released from the Hayden Creek Station reach the Pacific Ocean via Hayden Creek, Lemhi, Salmon, Snake, and Columbia rivers (Fig. 1).

The Hayden Creek Station rearing facilities consisted of two 0.24 hectare (0.6 acre) dirt bottom ponds approximately 2.1 meters deep and two concrete raceways (61.0 meters long x 1.2 meters wide). Water from a spring (11 C) or from Hayden Creek can be used in both the ponds and raceways.

The Hayden Creek Research Station was constructed in 1966 to investigate techniques in pond rearing of summer steelhead trout. Initially steelhead trout were to be reared one year in constant 11 C water. The 11 month period from egg collection (mid-May for Lemhi River adults) to release in mid-April was not sufficient to rear a large proportion of the fish to smolt size (Reingold 1975a).

1973 Rearing Program: Steelhead trout studied in 1973 from the Hayden Creek Research Station (Hayden Creek age II 1973 and Hayden Creek age II, mature males 1973) had been reared for two years (1971-1973). Fish in these groups originated from eggs collected in April and May of 1971 from adults returning to the Lemhi River weir, the Hayden Creek Station, and to Dworshak National Fish Hatchery. The fish were held in the raceways until October 1971, then transferred to one of the rearing ponds and held in natural Hayden Creek water temperatures until April 1973. Water temperatures in the pond ranged from 3.3 - 4.4 C (38 - 40 F) during the spring of 1973. After the first year of rearing, fish were allowed to leave the pond during the spring of 1972 and 4% of the fish in the pond did so (Reingold 1972). Reingold (1973) classified the fish released on April 3-4, 1973 as 61% top quality smolts (longer than 160 mm total[1/] length), 26% sub-smolts (shorter than 160 mm), and 13% precocial males. The average length of the fish released was 169 $\pm$ 43 mm (mean $\pm$ standard deviation), while fish classified as smolts averaged 197 $\pm$ 28 mm. On April 1, we collected our test fish from the pond and moved them to artificial stream channels at the Hayden Creek Station. Water temperatures in the channels ranged from 2.2-8.9 C (36-48 F) during April and May 1973.

1974 Rearing Program: Steelhead trout used in 1974 from the Hayden Creek Research Station were from a group reared two years (Hayden Creek age II 1974) and a group reared for one year (Hayden Creek age I 1974). Fish reared for two years prior to the 1974 release were also reared in the ponds, but the water temperature was increased during the 1972-73 winter months to increase growth rate. Voluntary first-year migrants were allowed to leave the pond during the spring of 1973. First year migrants averaged 159 $\pm$ 12 mm in length and made up less than 1% of the population in the pond (Reingold 1973). Originally the fish being reared for two years were to be released in April 1974, but they were released in November of 1973 to provide space for a group of steelhead trout to be reared for one year. At release, Mate (1974) classified 56% of the "two-year" fish as smolts (longer than 160 mm) and 44% as sub-smolts (shorter than 160 mm). The average length of fish released was 157 $\pm$ 30 mm. We retained a sample of the "two-year" fish in floating cages placed in the north rearing pond at the Hayden Creek Station for release in the spring of 1974.

[1/] Unless otherwise noted, all lengths reported are total lengths.

Steelhead trout used to evaluate one year of rearing at the Hayden Creek Station originated from eggs taken early in the spawning season at Dworshak National Fish Hatchery in 1973. In December 1973, steelhead trout fingerlings initially reared at the Hagerman Fish Hatchery were transferred to the Hayden Creek Station. The fingerlings averaged 105-110 mm in length and were two months ahead (growth-wise) of fingerlings resulting from adults returning to the Hayden Creek Station or the Lemhi River weir. The fish were reared for five months in the north pond at 11.7 $\pm$ 2.2 C (53 $\pm$ 2 F). At release on April 17, 1974, the fish averaged 163 $\pm$ 23 mm in length. Mate (1974) classified 27% of the released fish as sub-smolts (shorter than 160 mm), 73% as smolts (longer than 160 mm), and less than 1% precocial males.

In late January, an outbreak of Hagerman redmouth disease occurred in both the Hayden Creek age I 1974 and the Hayden Creek age II 1974 steelhead. Both groups were also treated in April with formalin to control a gill infestation of *Tricodina*.

Niagara Springs Trout Hatchery

Niagara Springs Hatchery, Pahsimeroi Collection Facility, and the Pahsimeroi acclimation ponds were constructed to mitigate for the loss of steelhead trout habitat upstream from Brownlee, Oxbow, and Hells Canyon dams on the middle Snake River. Idaho Power Company provided the funds and Idaho Department of Fish and Game personnel operated the facilities.

The Niagara Springs Steelhead Hatchery is located south of Wendell, Idaho adjacent to the Snake River (Fig. 2). The rearing facilities, built in 1966, consisted of 14 concrete raceways that measured 3.0 meters wide x 91.4 meters long x .9 meters deep. The water source for the hatchery is Niagara Springs a part of the Hagerman Valley aquifer. The water temperature is normally a constant 15 C (59 F) except during February of 1974 when the temperature dropped to 12-13 C for a couple of weeks.

Niagara Springs Hatchery is a part of the program to relocate the mid-Snake River steelhead trout stock to the Pahsimeroi River. Early in the program, eggs from adults collected below the Oxbow Dam were taken to Niagara Springs Hatchery for rearing to the smolt stage in one year. In the spring, smolts were transported to the Pahsimeroi River where they were allowed to migrate to the ocean.

The run has been successfully relocated to the Pahsimeroi River. Adult steelhead trout are trapped at the Pahsimeroi collection facility (Fig. 3), spawned, eggs incubated to the eyed stage, then shipped to the Niagara Springs Hatchery. At Niagara Springs Hatchery, juvenile steelhead trout are reared for one year, and then transported to the Pahsimeroi River during the March-May period where they are released into the river 1,320 river kilometers (820 river miles) from the Pacific Ocean (Hydrology Subcommittee 1965). The largest fish present at the hatchery are the first ones hauled with smaller fish kept at the hatchery until a later date to allow additional growth. Smolts migrating from the Pahsimeroi River reach the Pacific Ocean via the Salmon, Snake, and Columbia rivers (Fig. 1).

1973 Rearing Program: Steelhead trout studied in 1973 from the Niagara Springs Hatchery (Niagara Springs age I 1973) had been reared for one year (1972-73) and originated from eggs taken from adults returning to the Pahsimeroi River in 1972. Fish used to evaluate the downstream migration behavior were transported from Niagara Springs Hatchery and placed in a raceway at the Hayden Creek Station on February 15, 1973. Water temperature in the raceway averaged 11.7 ± 1.1 C (53 ± 1 F). On April 1, 1973, we moved the fish to an artificial stream channel located at the Hayden Creek Station. The water temperature in the stream channel ranged from 2.2 - 8.9 C (36 - 48 F).

1974 Rearing Program: In June 1973, the viral disease infectious pancreatic necrosis (IPN) was found in the 1973 year class of Pahsimeroi River stock steelhead trout fry being reared at Niagara Springs Hatchery. To prevent transmission to succeeding generations, all steelhead fry at Niagara Springs Hatchery were killed and burned (Reingold 1974). To replace fish destroyed at Niagara Springs Hatchery, Clearwater River steelhead fry (1973 year class) were transported from Dworshak National Fish Hatchery to Niagara Springs Hatchery for rearing and release in the spring of 1974.

In 1974, we evaluated two groups of steelhead trout on a one-year rearing program at Niagara Springs Hatchery. One group represented the largest, fastest growing fish present at the hatchery in February (Niagara Springs age I large 1974). The other group represented the normal production fish transported to the Pahsimeroi River (Niagara Springs age I 1974) and were smaller than the other group. This latter group contained individuals with slower growth rates or fish which grew rapidly, but originated from late egg takes. Steelhead trout from the two groups were transported from the Niagara Spring Hatchery just prior to tagging and release into Big Springs Creek. Fish in the large group held at the Niagara Springs Hatchery grew to even larger size by each succeeding release date whereas the production group fish were about the same length on each release date.

Niagara Springs - Pahsimeroi Ponds

The Pahsimeroi acclimation ponds (Fig. 2) are located next to the Pahsimeroi River approximately 32.5 river kilometers (14 river miles) upstream from the mouth of the Pahsimeroi River or 1336.3 river kilometers (830 river miles) upstream from the Pacific Ocean (Hydrology Subcommittee 1965). The ponds were originally designed for acclimation or imprinting of steelhead trout smolts to the Pahsimeroi River water after being reared at Niagara Springs Hatchery. Steelhead trout migrating from the acclimation ponds reach the Pacific Ocean via the Pahsimeroi, Salmon, Snake, and the Columbia rivers (Fig. 1).

The ponds were approximately 13.7 meters wide and 152.4 meters long with removable water driven rotary screens at the inlet and outlet. Water was diverted into the ponds from the Pahsimeroi River and averaged 4.4 C (40 F) in March and 7.8 C (46 F) in May 1974.

Steelhead trout studied in 1974 from a Pahsimeroi pond (Niagara - Pahsimeroi age II 1974) had been reared for two years (1972-1974). They originated from eggs collected from adults returning to the Pahsimeroi River in 1972 and were reared for one year at the Niagara Springs Hatchery and the second year in a Pahsimeroi acclimation pond. These fish were not large enough to become smolts after one year of rearing at Niagara Springs hatchery. The fish were delivered to the pond in the summer of 1973 and the pond was evacuated in early May 1974.

METHODS OF ASSESSING PARR-SMOLT TRANSFORMATION

In this study, we used appearance, coefficient of condition, NaK-ATPase activity, saltwater tolerance, and migratory behavior as indexes of the transformation from parr to smolt in juvenile steelhead trout. We studied wild steelhead trout in Big Springs Creek and the Lemhi River and hatchery fish from three cultural facilities. We evaluated the effects of release time, size, age, rearing condition, and cold water conditioning on transformation (as measured primarily by migratory behavior).

Appearance

We assigned each individual fish to a category of parr, intermediate, or smolt based on body coloration. We used a coloration criteria similar to the criteria that Wagner (1970) used for winter steelhead trout on the Alsea River in Oregon.

Parr: No apparent silvering, body color yellowish-brown, belly dark, parr marks dark and clearly delineated; ventral and anal fins dark colored with tinge of white on edge.

Intermediate: Moderate degree of silvering confined to the anterior of the body, parr marks light in color and more or less indistinct.

Smolt: Moderate to heavy silvering, belly light in color, parr marks absent or just visible, back an iridescent blue or greenish blue, caudal fin commonly with a black band on posterior edge.

Coefficient of Condition

We used the mean coefficient of condition as an index of parr-smolt transformation for each group of fish studied. We weighed and measured a random sample of 25-100 anesthetized fish each month from each group. Individual fish were weighed to 0.1 g and total length measured to the nearest millimeter. We calculated the coefficient of condition for each fish in a sample using the formula $K = 100\ W/L^3$, where W denotes weight in grams and L denotes total length in centimeters (Hoar 1939).

NaK-ATPase Activity

We determined Na^+, K^+ - stimulated ATPase activity (NaK-ATPase) from preparations of gill microsomes. We trimmed the gill filaments (0.2 g wet weight - blotted) from the arches of individual fish as described by Zaugg and McLain (1971) and determined the gill NaK-ATPase activity by the method described by Zaugg and McLain (1970). Inorganic phosphate released by the NaK-ATPase activity was determined indirectly by an atomic absorption spectrophotometer using an oxygen-nitric oxide flame and a wave length of 390 mu. The NaK-ATPase activity is expressed as μ moles of ATP hydrolyzed/hr per mg protein. We measured the protein concentration by the method of Lowry et al. (1951) as modified by Miller (1959).

Saltwater Tolerance

To assess the saltwater tolerance for each group of fish, we placed fish in closed systems of both freshwater and saltwater. Each system consisted of a biological filter, an ultraviolet filter, and four 750 liter holding tanks. Water was pumped to each tank from the sump of the biological filter at 300 liters per minute per tank. The holding tanks were aerated by compressed air and by jetting water into each tank. Overflow water from each tank flowed by gravity back to the biological filter. Each tank had approximately a 2½ hour turnover time.

The biological filter consisted of four sections. The first section functioned as a sump for water returning from the holding tanks. The second section contained crushed rock (1 to 2.5 cm) as substrate for denitrifying bacteria. The third section contained crushed rock, charcoal to detoxify the system, and oyster shells to maintain the pH. The fourth section functioned as the sump from which water was pumped to the holding tanks. Approximately one-fourth of the water pumped to the holding tanks passed through an ultraviolet filter to control bacteria in the system. Water temperature was controlled at 10 C (50 F) by the ambient air temperature in the temperature controlled room.

Each month we exposed fish from each group to saltwater (Instant Ocean Salts, 30 to 32 ppt; Aquarium Systems Ins., Eastlake, Ohio) by immediate transfer from the freshwater system to the saltwater system. We brought fish to the lab, acclimated them for a minimum of 3-4 days in freshwater and then placed 10-50 fish from each group into saltwater. The saltwater tolerance test lasted for 10 days or until all fish died. No feed was given during the acclimation or saltwater tolerance test. We calculated the percentage saltwater survival as the number of fish which survived in saltwater for the full 10 days. The percentage survival and median lethal time provided a gross measurement of osmoregulatory ability.

Migratory Behavior

We monitored the initial seaward migration of wild and hatchery steelhead trout in Big Springs Creek and the Lemhi River. Big Springs Creek and the Lemhi River flow through the Lemhi Valley in east-central Idaho adjacent to the Idaho-Montana border (Fig. 1). The Lemhi River (90.3 km in length) flows through a broad valley before it enters the

Salmon River. Several springs rise 1.6 km northwest of Leadore to form Big Springs Creek (8.0 km in length) which parallels and enters the Lemhi River 77.2 river kilometers (48 river miles) from its junction with the Salmon River. Smolts migrating from Big Springs Creek reach the Pacific Ocean (1319 river kilometers downstream) via the Lemhi, Salmon, Snake, and Columbia rivers (Fig. 1).

Discharge remains relatively stable in both Big Springs Creek and the upper Lemhi River. Big Springs Creek normally discharges 0.8-1.0 m^3/sec (30-36 cfs) and the upper Lemhi River discharges about 3.4-5.1 m^3/sec (120-180 cfs) during all but the spring runoff (Bjornn 1971). In 1973, maximum discharge from a below-average snowpack reached 16.5 m^3/sec (584 cfs) on June 15 as measured at the gauging station on the Lemhi River at river kilometer 46.3.

In 1974, the water temperature at the Big Springs Creek weir ranged from 5.5 C in March to 12.2 C in June. The temperature of Big Springs Creek usually exceeded that of the Lemhi River at the weir sites.

The waters of Big Springs Creek and the Lemhi River were considered to be relatively productive as indicated by the pH, alkalinity and hardness (Bjornn 1966). Goodnight and Bjornn (1971) estimated annual fish production in Big Springs Creek at 11.8 g/m^2/yr and in the upper Lemhi River 13.6 g/m^2/yr. The following fish species were found in Big Springs Creek: steelhead trout, rainbow trout, chinook salmon (*Oncorhynchus tshawytscha*), brook trout (*Salvelinus fontinalis*), Dolly Varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), sculpin (*Cottus* sp), and dace (*Rhinichthys* sp).

We used two fish weirs to monitor the initial downstream fish movement, one in Big Springs Creek and the other in the upper Lemhi River (Fig. 3). The Big Springs Creek weir was located approximately 60 m upstream from its junction with the Lemhi River. The Lemhi River weir was located 48.7 river kilometers (30 river miles) from its junction with the Salmon River and approximately 24.2 river kilometers (15 river miles) downstream from the Big Springs Creek weir.

The weir at Big Springs Creek consisted of a large rotary drum screen, emergency drop gates, and a bypass trap. The entire flow of the stream passed through the rotary screen. Fish moving downstream were guided along the rotary drum screen into the bypass trap.

The downstream migrant trap in the Lemhi River consisted of a louver array which guided fish into a bypass trap. The percentage of the downstream migrants that we captured in the louver trap depended on fish size, river flow, and distribution of the fish across the stream. Tests conducted on the efficiency of the Lemhi River collection facility indicated that more than 95% of the juvenile steelhead entering the louver system were captured in the trap (Bjornn 1966). More detailed descriptions of both weir facilities appear in Bjornn (1966 and 1968) and Holubetz (1967).

Personnel of the Idaho Department of Fish and Game checked the weirs regularly unless ice formation or equipment breakdown prevented operation. The Big Springs Creek weir was operated from March 18 to July 31 in 1973 and from March 3 to July 31 in 1974. In 1973 the Lemhi River weir was operated from March 1 to July 31 and in 1974 from March 5 to July 31.

We enumerated the number of wild steelhead trout migrants captured at the weir facilities, and estimated the total number of migrants each week by multiplying the number of days in the week by the number of migrants captured per night when the weir was operated (usually 5 nights per week). We periodically measured to the nearest millimeter a random sample of the wild steelhead trout collected at the two weir sites.

We released tagged hatchery steelhead trout into Big Springs Creek on a set schedule (Table 1) and enumerated the downstream migrants at the Big Springs Creek weir. Before release, each hatchery fish was measured, classified as to appearance, and tagged with a numbered jaw tag (National Band and Tag Company, Newport, Kentucky) or a numbered floy tag (Floy Tag Manufacturing Company, Seattle, Washington). Only immature fish larger than 150 mm total length were tagged and released. Precocious males were not included in the test groups because smolting and precocious sexual development appear to be incompatible biological processes (Evropeitseva 1960). Wagner et al. (1963) established 140 to 160 mm fork length as the critical size for smoltification and seaward migration of winter steelhead trout reared in a hatchery. We used Wagner's size criteria as the basis for not tagging fish smaller than 150mm total length. We assumed tagging mortality was equal between release groups and between release dates.

We released all tagged, hatchery steelhead trout into Big Springs Creek, approximately 5.9 river kilometers (3.7 river miles) upstream from the Big Springs Creek weir (Fig. 3). Tagged fish subsequently collected at the Big Springs Creek weir trap were enumerated, measured, classified as to appearance, and the tag number recorded.

We used electrofishing gear in early July of 1973 and 1974 to assess the distribution and abundance of tagged hatchery steelhead trout which held over or residualized in Big Springs Creek. Rather than try to sample the entire length of Big Springs Creek, we estimated the fish abundance in six sample sections of Big Springs Creek. The first sample section was located directly above the weir and the sixth sample section was located a short distance downstream from the release site. The remaining four sample sections were distributed evenly between the upper and lower sections. Each section was approximately 122 meters (400 feet) in length and consisted of a series of pools and riffles with shallow riffles at each end to minimize movement of fish into and out of the section during sampling. We sampled 11.9% in 1973 and 12.6% in 1974 of the total stream area in Big Springs Creek.

Table 1. Wild and hatchery steelhead trout tagged and released into Big Springs Creek during 1973 and 1974. Wild fish were collected at the Big Springs Creek weir and hatchery fish were from the Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery.

Year	Release group	Release date	Number tagged	Mean length (mm)
1974				
	Wild fish	4/28	184	191
	Hayden Creek Age II	3/2	500	180
		3/30	500	184
	Hayden Creek Age I	3/2	500	169
		3/31	500	173
		4/28	500	181
		6/1	332	184
	Niagara-Pahsimeroi Age II	3/30	1000	210
	Niagara Springs Age I	3/2	500	169
		3/30	500	183
		4/27	491	203
		6/1	495	209
	Niagara Springs Age I (conditioned)	3/30	500	177
		4/27	83	170
		4/27	348	184
		4/28	463	198
		6/1	127	206
1973				
	Hayden Creek Age II	4/1	546	210
		4/28	752	203
		6/3	661	205
	Hayden Creek Age II (mature males)	4/1	476	219
		4/28	278	214
		6/3	233	215
	Niagara Springs Age I	3/31	1041	176
		4/28	1000	178
		6/2	700	182

We made two consecutive electrofishing passes through each sample section (fishing up and down during a pass) and removed all fish captured each time. We attempted to maintain a constant fishing effort during each pass. We recorded the number of fish, the tag number, appearance, and the length of all tagged steelhead trout collected during each pass.

We estimated the number of hatchery steelhead trout in the creek by the two-catch method (Seber and LeCren 1967) in the six sample sections of Big Springs Creek. We expanded the estimate for the sample sections to all of Big Springs Creek. The estimated number of fish which held over or residualized from each release group was based on the proportion of fish from each group recovered in the sample sections.

In 1973 and 1974, Idaho Department of Fish and Game personnel marked and released a group of steelhead trout into Hayden Creek from the Hayden Creek Station and into the Pahsimeroi River, a group from the Pahsimeroi ponds and 6 groups from Niagara Springs Hatchery (Table 2). National Marine Fisheries Service (NMFS) personnel collected samples of fish at the Snake River dams and recorded the number of fish captured from each mark group. We utilized their data to evaluate the migration of smolts through the lower Snake River. Additional information on the groups of fish released are provided by Reingold (1975a for Hayden Creek fish) and Reingold (1974 and 1975b) for Niagara Springs fish.

We used data collected by National Marine Fisheries Service personnel to evaluate the migration of wild and hatchery steelhead trout in the lower Salmon, Snake, and Columbia Rivers. Personnel of the National Marine Fisheries Service recaptured marked fish at Riggins on the Salmon River, at Little Goose Dam (1973 only) and Ice Harbor Dam on the lower Snake River, and at the Dalles Dam on the Columbia River (Fig. 1). The recovery sites were located 909.0 river kilometers (565 river miles), 636.0 river kilometers (395 river miles), 537.7 river kilometers (334 river miles), and 308.2 river kilometers (191 river miles), respectively, upstream from the Pacific Ocean (Hydrology Subcommittee, 1965 and 1972).

Steelhead trout smolts migrating down the Salmon River were captured in a self-cleaning scoop trap at Riggins. A collection system located at the end of the turbine bypass system was used at Little Goose and Ice Harbor Dams to collect steelhead trout migrating down the Snake River (Park and Farr 1972; Ebel et al. 1973a). Turbine intake gatewells were sampled at The Dalles Dam on the Columbia River by dipnetting as described by Bentley and Raymond (1968). The 1973 and 1974 sampling schedules at the various recovery locations are present in Table 3 (Raymond et al. 1974 and 1975). National Marine Fisheries Service personnel recorded all marked fish recovered and measured each marked fish (fork length). We converted their fork length measurements to total length by using the formula $TL = 4.90 + 1.03\ FL$ ($r = .996$) for comparison with our release and recovery data.

Table 2. Hatchery steelhead trout marked and released by Idaho Department of Fish and Game personnel during 1973 and 1974. Fish from the Hayden Creek Station and Pahsimeroi pond were released at the rearing site. Fish from Niagara Springs Hatchery were released into the Pahsimeroi River.

Hatchery	Mark[a]	Release date	Number marked	Mean length (mm)	Release site
Hayden Creek	LV	4/3-4/73	13,800	169	Hayden Creek Hatchery
Pahsimeroi Ponds	LV	4/5/74	25,000	210	Pahsimeroi Acclimation Pond
Niagara Springs	LVAD	3/11/74	20,000	169	Pahsimeroi Acclimation Pond
	RVAD	4/1-3/74	20,000	168	Pahsimeroi Acclimation Pond
	RV	5/2-5/74	20,000	173	Pahsimeroi Acclimation Pond
Niagara Springs	LVAD	3/4-9/73	20,000	177	Pahsimeroi Collection Facility
	RVAD	4/9-11/73	20,000	174	Pahsimeroi Collection Facility
	RV	5/3/73	20,000	179	Pahsimeroi Collection Facility

[a]Fin clips: LV = left ventral, RV = right ventral, LVAD = left ventral - adipose, RVAD = right ventral-adipose.

Table 3. Sampling schedule at the Big Springs Creek and Lemhi River weirs, Riggins scoop trap, and at Little Goose, Ice Harbor, and The Dalles dams during 1973 and 1974.

Fish collection site	1973	1974
Big Springs Creek weir	March 18-July 31	March 3-July 31
Lemhi River weir trap	March 1-July 31	March 5-July 31
Riggins scoop trap	March 8-July 12	March 23-May 26
Little Goose Dam	April 8-June 16	-
Ice Harbor Dam	April 16-Dec. 11	April 4-June 19
The Dalles Dam	April 4-Dec. 17	Feb. 10-Dec. 31

CHARACTERISTICS OF FISH DURING PARR-SMOLT TRANSFORMATION

Appearance

The silveriness produced by increasing amounts of the purines, quanine and hypoxanthine, beneath the scales and in the dermis adjacent to the muscle is an obvious, but hard to quantify, indicator of parr-smolt transformation. Johnston and Eales (1967 and 1970) found transition from parr to silvery parr to smolt stage was correlated with scale purine deposition in Atlantic salmon. They suggested that silvering was strongly size dependent with the larger fish developing an earlier smolt appearance. Neither lengthening photoperiod nor increasing temperature had any marked effect on the onset of silvering, although increasing temperature during the spring did increase the amount of purine deposited in the skin (Johnston and Eales 1968).

We observed three phases of body coloration changes of summer steelhead trout during parr-smolt transformation. During the first phase, the silvering of the fish, became distinguishable in February and March and progressed rapidly in April. The parr marks were distinguishable under a thin purine layer. The fish had a metallic gloss, according to the light, and the scales became easily detached. The tip of the dorsal and caudal fin began to darken.

The second coloration phase (intermediate stage) continued from April to early May. The parr marks on the body were still distinguishable in certain light conditions but the silvery color deepened. The backs of most fish appeared gray or brownish-gray with an iridescent appearance. The tip of the dorsal and caudal fin became fairly dark.

The third coloration phase (smolt stage) represented steelhead at the end of parr-smolt transformation. Fish at this stage were observed from late April to late May. The silvering of the body surface became so condensed that the parr marks were difficult to recognize. The tip of the dorsal and caudal fins became very dark or black. The scales were extremely easy to remove. The backs of most fish were iridescent blue or bluish-gray.

After the migration season, the fish regressed from smolt to parr, and by July had lost all smolt appearances. The silvery color faded and the parr marks gradually became more pronounced. The dark tinge at the end of the dorsal and caudal fins also faded.

Wild steelhead trout from Big Springs Creek and hatchery fish from Hayden Creek Station and the Pahsimeroi pond (Niagara - Pahsimeroi age II) had a larger proportion of smolt appearing fish than the steelhead trout reared at Niagara Springs Hatchery (Fig. 4). Fish reared in the warmer water at Niagara Springs were less silvery than fish reared in the cooler water at Hayden Creek Station or the Pahsimeroi pond. Based on the appearance data, less than half the normal-sized age I steelhead trout from Niagara Springs had developed the full smolt appearance when

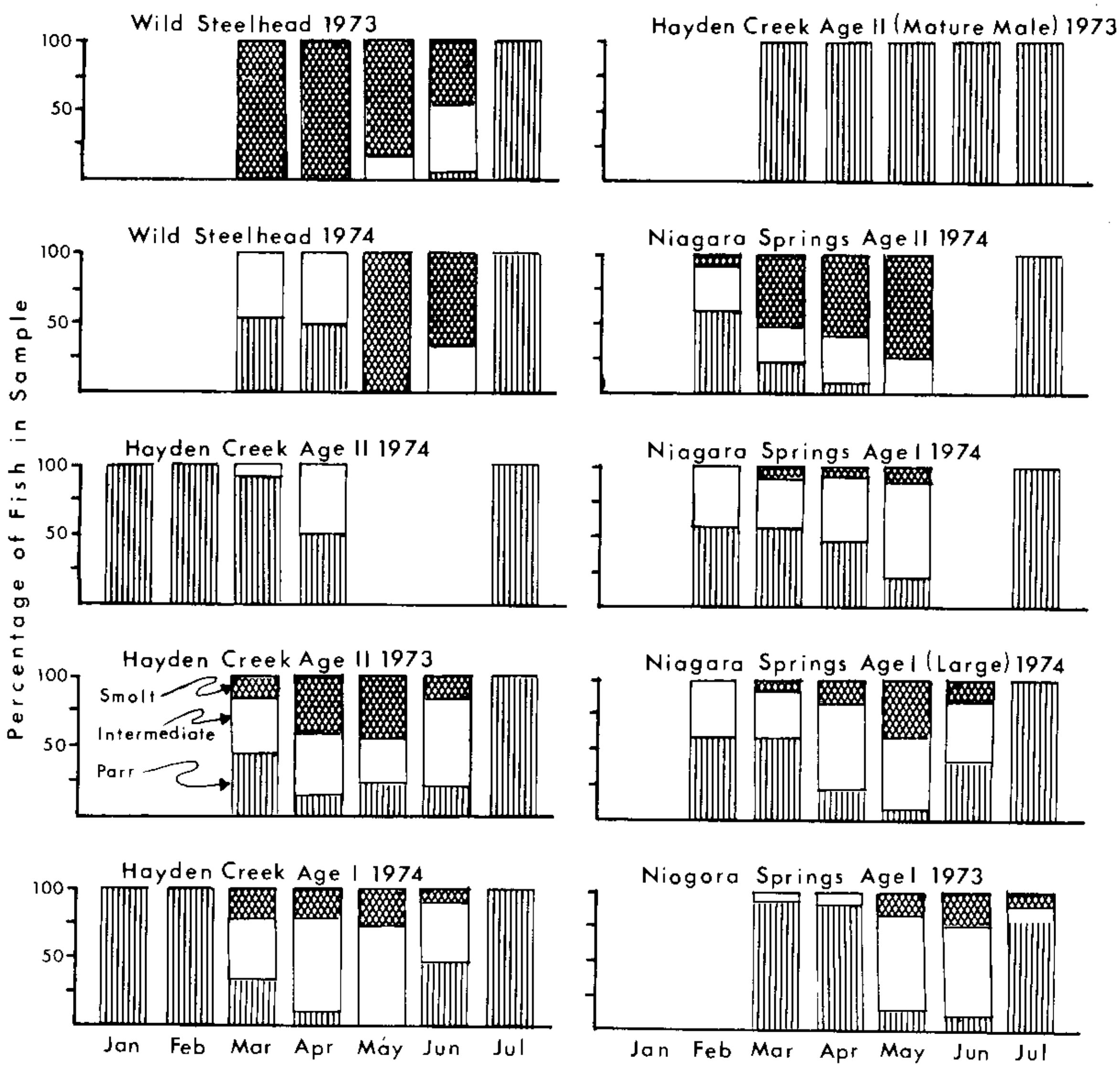

Figure 4. Seasonal changes in appearance (parr, intermediate, and smolt) of wild (collected from the Big Springs Creek weir) and hatchery (from Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery) steelhead trout, 1973-74.

released (Fig. 4). More of the Niagara Springs age I large group of fish had a smolt appearance than the Niagara Springs age I normal-size fish. Mature males from the Hayden Creek Station did not change in body appearance.

Most hatchery steelhead trout migrating from Big Springs Creek in May and June had developed the silvery smolt appearance (Fig. 5). The few fish from the early releases which migrated soon after release did not have the full smolt appearance. All marked hatchery fish recaptured at Riggins and Little Goose dams had the smolt appearance (Table 4).

Coefficient of Condition

The coefficient of condition, as measured by the weight-length relationship, changes during parr-smolt transformation in several of the anadomous salmonids. Evropeitseva (1957) found that Atlantic salmon smolts differed from parr in having a longer and thinner caudal peduncle and less body depth. Fessler and Wagner (1969) observed that winter steelhead trout had a decrease in body and caudal peduncle depth during the migratory period. The marked decrease in the coefficient of condition during smoltification is followed by a rapid increase in condition factor if the fish remains in fresh water past the migration season (coho salmon, Vanstone and Marker 1968; Atlantic salmon, Evropeitseva 1957; Houston and Threadgold 1963; Johnston and Eales 1968 and 1970; Pinder and Eales 1969; Saunders and Henderson 1970; winter steelhead trout, Fessler and Wagner 1969; Wagner 1974a; summer steelhead trout, Bjornn 1966; Fessler 1971 and 1973; Adams et al. 1973; Everest 1973). Fessler and Wagner (1969) and Pinder and Eales (1969) found a significant correlation between lipid content and changes in the coefficient of condition during parr-smolt transformation.

Changes in coefficient of condition during parr-smolt transformation is size dependent (Fessler and Wagner 1969). Fessler and Wagner observed that migrant-sized (longer than 160 mm fork length) winter steelhead trout had a decrease in coefficient of condition during the migratory period, whereas non-migrants (shorter than 160 mm) did not.

The mean coefficient of condition of wild and hatchery summer steelhead trout we studied was smaller during the pre-migratory and migratory period than during the post-migratory period (Fig. 6). Changes in coefficient of condition reflected morphological changes at the time of parr-smolt transformation. The monthly mean coefficients of condition of wild steelhead trout migrating from Big Springs Creek ranged from 0.698 ± 0.049 (mean $\pm$ standard deviation) to 0.789 ± 0.091 in 1973 and from 0.734 ± 0.054 to 0.772 ± 0.071 in 1974, but were not significantly different during the migration season (Table 5). The coefficient of condition of wild rainbow-steelhead collected from Big Springs Creek by electrofishing in July (0.974 ± 0.141 in 1973 and 0.936 ± 0.146 in 1974) was significantly larger than that of the migrants.

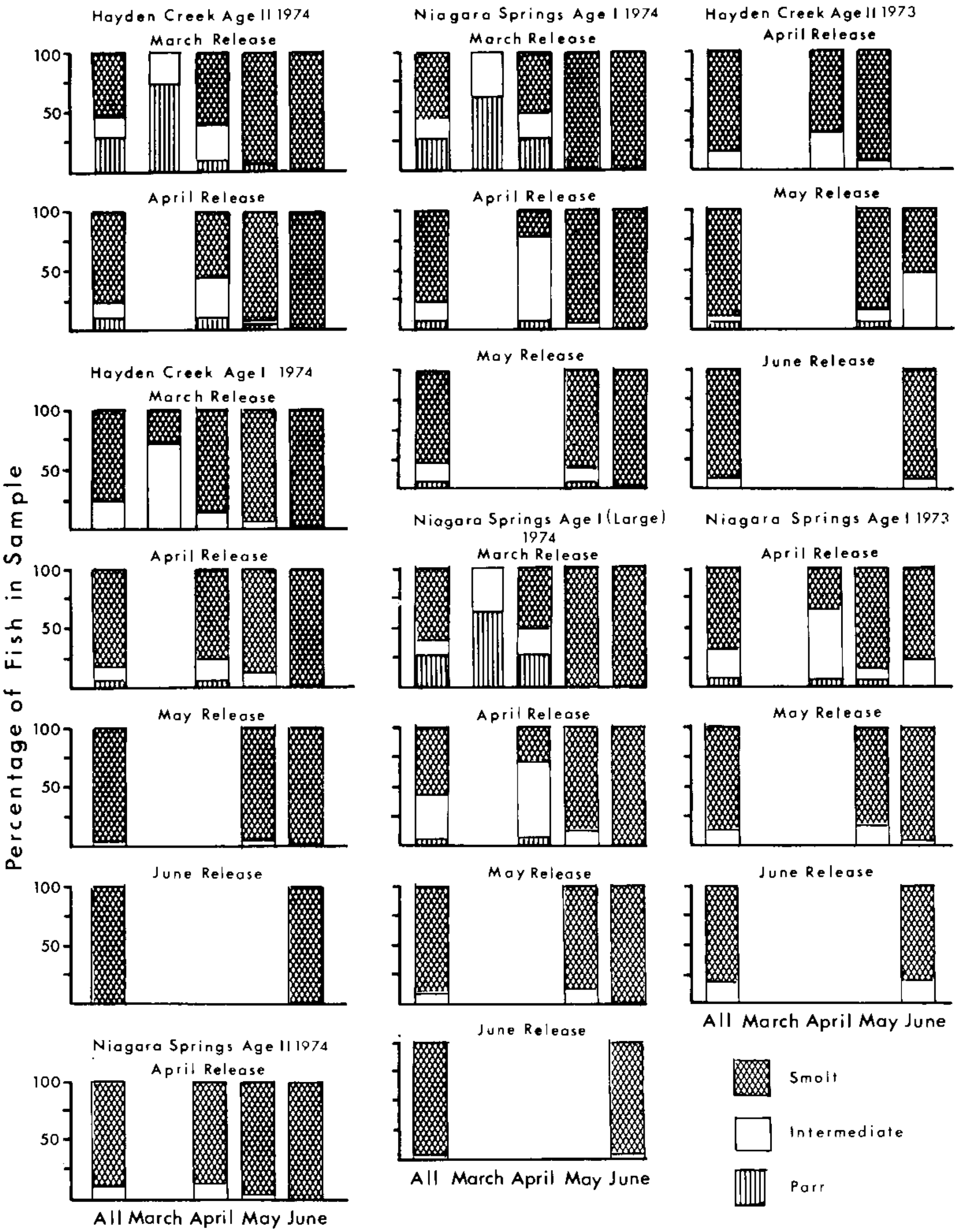

Figure 5. Seasonal changes in the percentage of hatchery steelhead trout classed as smolt, intermediate, or parr when recaptured at the Big Springs Creek weir, 1973-74. Data presented for groups released each month by month of migration.

Table 4. Appearance, length, and coefficient of condition of hatchery steelhead trout released into Big Springs Creek, Hayden Creek, and the Pahsimeroi River and recaptured at Big Springs Creek weir, Riggins scoop trap, and at Little Goose, Ice Harbor, and The Dalles dams 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other (P ≤ 0.05).

Characteristic and Release group	Big Springs		Riggins	Little Goose	Ice Harbor	The Dalles	F
	Release	Migrants					
Appearance [a]							
Niagara-Pahsimeroi Age II 1974	98	100	100	100			
Niagara Springs Age I 1974	61	90	100				
Length (mm)							
Niagara-Pahsimeroi Age II 1974	210	216	230	264	198	235	39.07**[b]
Niagara Springs Age I 1974	170	184	175		185	192	122.23**
Hayden Creek Age II 1973	210	221			192	214	103.37**
Niagara Springs Age I 1973	180	196			192	252	216.99**
Coefficient of Condition							
Niagara-Pahsimeroi Age II 1974	.740	.716	.700	.655			2.53
Niagara Springs Age I 1974	.854	.760	.781				0.02

[a] Appearance was expressed as percentage of fish with smolt and intermediate appearance.

[b] * = Significant at P ≤ 0.05 and ** = significant at P ≤ 0.01.

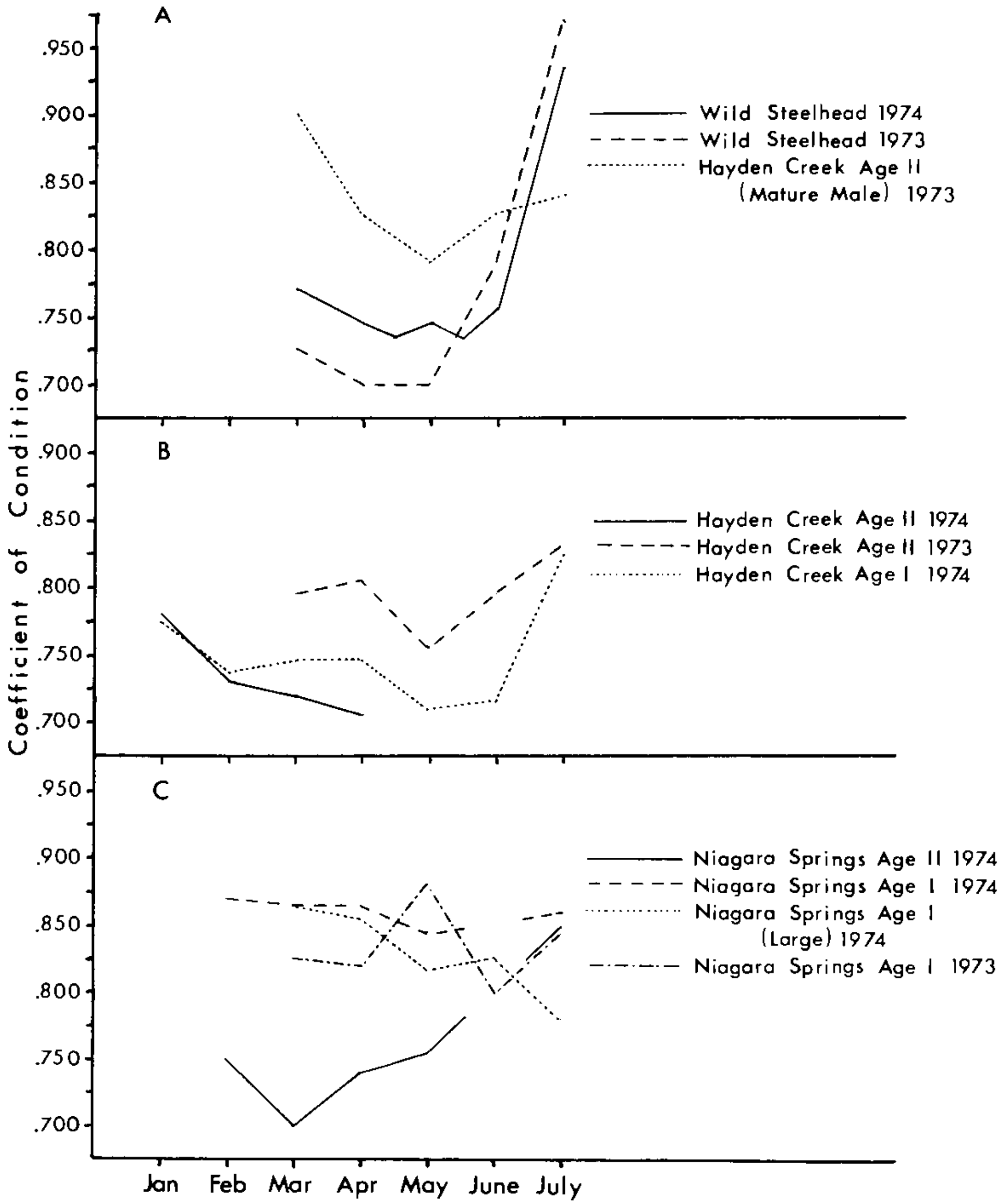

Figure 6. Seasonal changes in mean coefficient of condition of wild (collected at the Big Springs Creek weir) and hatchery (from Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery) steelhead trout, 1973-74.

Table 5. Mean coefficients of condition of wild steelhead trout collected at the Big Springs Creek weir and hatchery steelhead trout at Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

Release group	Coefficient of condition for each month: Jan	Feb	March	April		May		June	July	F
Wild steelhead 1974			0.772	0.746	0.734	0.744	0.737	0.756	0.936	22.32^{**a}
Wild steelhead 1973			0.721	0.700		0.698		0.789	0.974	85.65^{**}
Hayden Creek age II 1974 (mature males)			0.899	0.827		0.788		0.826	0.843	26.75^{**}
Hayden Creek age II 1974	0.780	0.729	0.719	0.706						17.96^{**}
Hayden Creek age II 1973			0.795	0.806		0.755		0.794	0.829	10.37^{**}
Hayden Creek age I 1974	0.776	0.736	0.747	0.746		0.712		0.713	0.818	22.39^{**}
Niagara-Pahsimeroi age II 1974		0.751	0.706	0.740		0.757			0.848	20.67^{**}
Niagara Springs age I 1974		0.859	0.857	0.860		0.841			0.854	.71
Niagara Springs age I large 1974		0.859	0.857	0.851		0.815		0.822	0.781	12.41^{**}
Niagara Springs age I 1973			0.820	0.815		0.878		0.797	0.850	11.77^{**}

[a] * Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

The wild steelhead trout we monitored and native winter steelhead trout migrants observed by Wagner (1969) did not have the vernal decrease in the coefficient of condition associated with parr-smolt transformation seen in hatchery fish. Bjornn (1966) measured the coefficient of condition of juvenile rainbow-steelhead trout through the first two years of life in Big Springs Creek. The coefficient was largest during the first summer of life, declined to a smaller value during the subsequent winter, increased during the second summer of growth in the stream, decreased during the following winter, and then increased slightly during the spring months as the smolts began their migration to the sea. The coefficient increased during March, April, and May of the fishes first spring but remained low during the second spring until after the migration season.

The non-smolting age II mature males from the Hayden Creek Station in 1973 had a seasonal decrease in coefficient of condition (Fig. 6A), but the mean coefficient during April and May was larger than for wild steelhead trout or age II hatchery fish (Fig. 6B). Fessler (1973) observed a vernal decrease in the coefficient of condition of migrating summer steelhead and resident rainbow trout in the Deschutes River, Oregon. The mean coefficient was 0.125 to 0.175 larger for the resident rainbow than for the migrating steelhead trout.

Steelhead trout reared at the Hayden Creek Station had the typical vernal decline in coefficient of condition associated with parr-smolt transformation (Fig. 6B). The coefficients varied between the groups, but the pattern was similar for all groups. The differences observed between age II steelhead trout in 1974 and age II fish in 1973 from Hayden Creek Station can be attributed to a difference in size; the 1974 fish were longer. Kesteven (1947) stated that the coefficient of condition for most species of fish increased as the length of the fish increased.

For the age II steelhead trout reared at Niagara Springs Hatchery the first year and in a Pahsimeroi pond the second, the smallest mean coefficient of condition occurred in March (Fig. 6C). The trend of the coefficients of condition may indicate an earlier onset of parr-smolt transformation for the Niagara - Pahsimeroi age II fish released in 1974.

The age I fish reared at Niagara Springs Hatchery did not exhibit a decline in coefficient of condition similar to that in other groups of hatchery fish (Fig. 6C). The mean coefficient for the normal-sized steelhead trout in 1974 did not change significantly in April and May, but the coefficient of the larger steelhead was significantly smaller in May and June than in earlier months (Table 5). The coefficients observed for normal and large sized, age I fish reared at Niagara Springs Hatchery (Fig. 6C) was similar or larger than the values for the non-smolting mature males from Hayden Creek Station (Fig. 6A).

The coefficient of condition for the large age I fish from Niagara Springs Hatchery released in 1974 did not increase during the June-July period for an unexplained reason. Reingold (1968, 1969, and 1970) observed that the coefficient of condition of hatchery steelhead trout which remained in the Pahsimeroi River after the migration season decreased throughout the summer and fall. He attributed the decline to the failure of the fish to feed or to get enough to eat.

Wild steelhead trout collected at the Big Springs Creek weir in 1974 had a significantly higher mean coefficient of condition ($F = 29.42$; $df = 4{,}524$; $P \leq 0.01$) than fish collected at all lower river recovery sites (Fig. 7 and Table 6). The mean coefficient of condition of wild steelhead trout from Big Springs Creek was $.698 \pm .048$ ($N = 125$) in 1973 and $.743 \pm .064$ ($N = 120$) in 1974.

The coefficient of condition of wild steelhead trout from Big Springs Creek or the lower river recovery sites did not change significantly ($F = 0.84$; $df = 5{,}129$; $P \leq 0.05$) during the migration season (Table 7). Fessler and Wagner (1969) observed little seasonal change in the coefficient of condition of wild winter steelhead trout collected from the Sandy River, Oregon.

The mean coefficients of condition of hatchery steelhead trout when released and when migrating past the Big Springs Creek weir, Riggins scoop trap, or Little Goose Dam was not significantly different (Table 7). Fessler and Wagner (1969) observed that downstream migrating winter steelhead trout recaptured the first few days after release had a lower mean coefficient of condition than the fish released and the coefficient of migrants continued to decline until late June. We observed the same general trend, but the differences were not significant because of the small numbers of migrants measured and weighed.

The vernal decline in coefficient of condition for steelhead trout undergoing parr-smolt transformation reflects the alteration in chemical composition of the body lipids (Fessler and Wagner 1969, Pinder and Eales 1969). The decrease in lipid content may be due to an increased growth rate with a channeling of foods into protein. Lovern (1934) reported that the lipids of Atlantic salmon not only declined during parr-smolt transformation but also changed qualitatively to fats of a higher unsaturated type. This qualitative change might be related to the lipids of cell membranes and their properties of permeability. The change in lipids may be an essential part of the transition from living in freshwater to living in a seawater environment.

The decline in coefficient of condition may also be a reflection of the increased activity of smolts. Fish undergoing parr-smolt transformation have been observed to exhibit increased activity and alertness to stimuli (Hoar et al. 1957, Pinhorn and Andrews 1965). Baraduc and Fontaine (1955) reported an increase in the rate of metabolism at the time of parr-smolt transformation. This could increase energy demands with the utilization of certain kinds of fats.

Kesteven (1947) listed several variables that could affect the coefficient of condition. Among the variables that are applicable to fish in the present study are genetic capacity for growth, seasonal

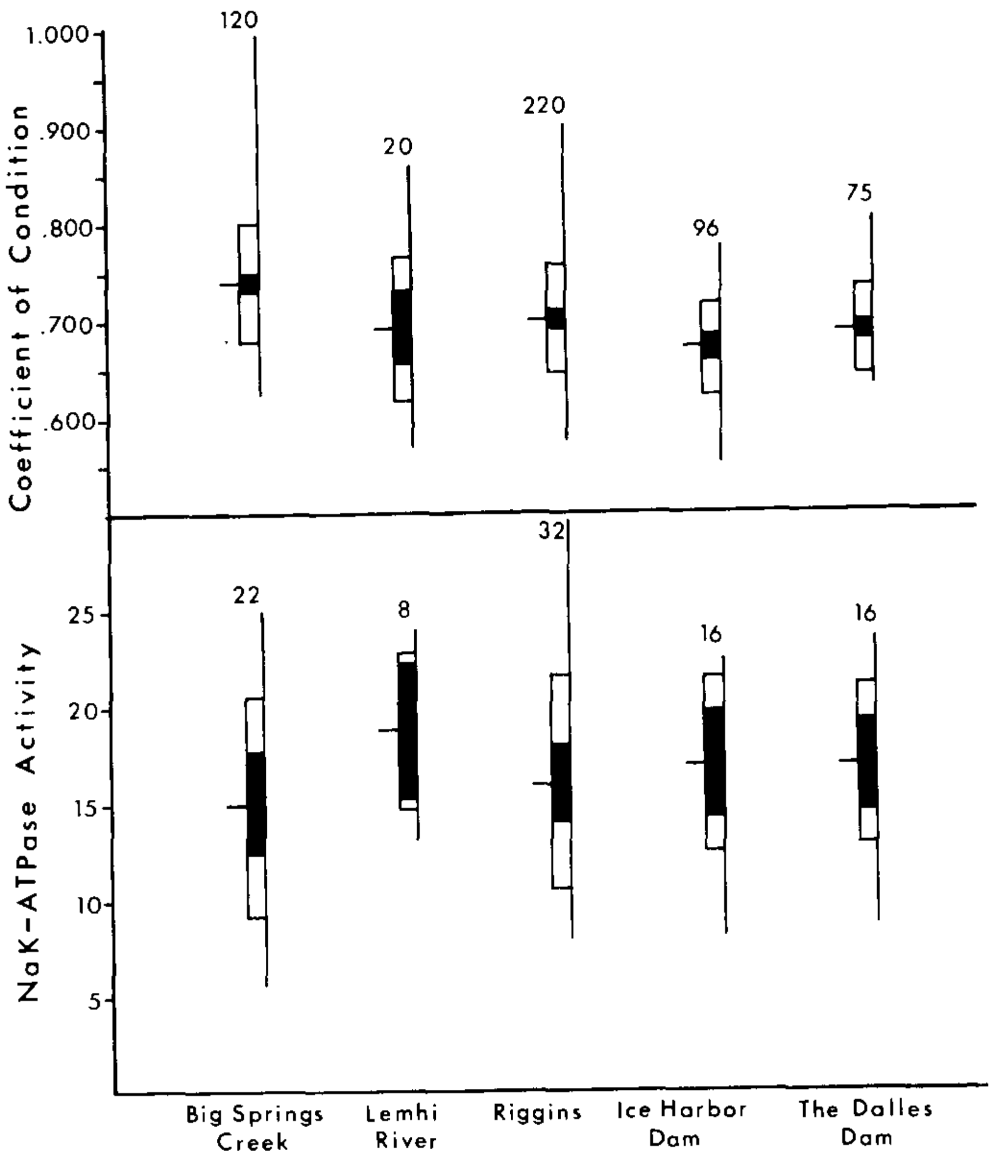

Figure 7. Coefficient of condition and NaK-ATPase activity of wild steelhead trout collected at the Big Springs Creek weir, Riggins scoop trap, and Little Goose, Ice Harbor, and The Dalles dams, April through June, 1974. NaK-ATPase activity is expressed as μ moles of ATP hydrolyzed/hr per mg protein. Vertical line = range, rectangle = standard deviation, black rectangle = 95% confidence interval, and the horizontal line = mean.

Table 6. Appearance, length, coefficient of condition, and NaK-ATPase activity of seaward migrating wild steelhead trout collected at the Big Springs Creek and Lemhi River weirs, Riggins scoop trap, and Little Goose, Ice Harbor, and the Dalles dams during April through June, 1974. Means underlined by a continuous single line are not significantly different from each other ($P \leq 0.05$).

Characteristic	Big Springs	Lemhi River	Riggins	Little Goose	Ice Harbor	The Dalles	F
Appearance[a]							
	94		100	100	100	100	
Length (mm)							
	187	196	188	191	189	189	53.80**[b]
Coefficient of Condition							
	.743		.692	.699	.668	.686	29.42**
NaK-ATPase Activity							
	15.1		18.6	16.1	17.1	16.8	1.84

[a] Appearance was expressed as percentage of fish with smolt and intermediate appearance.

[b] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 7. Appearance, length, coefficient of condition, NaK-ATPase activity, and saltwater tolerance of seaward migrating wild steelhead trout collected at the Big Springs Creek weir, Riggins scoop trap, and Little Goose, Ice Harbor, and the Dalles dams during April through June, 1974. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

Characteristic	Month sampled							
	March	April		May		June		Mean
Collection site	1	1	15	1	15	1	F	(sample size)
Appearance[a]								
Big Springs Creek	53	55		100		100		94 (294)
Riggins					100			100 (20)
Little Goose Dam			100	100	100	100		100 (220)
Ice Harbor Dam			100		100	100		100 (90)
The Dalles Dam			100		100	100		100 (75)
Length (mm)								
Big Springs Creek	190	191		195		183	19.25**[b]	193 (1629)
Riggins					188			188 (163)
Little Goose Dam			196	191	187	189	3.11*	191 (225)
Ice Harbor Dam			194	189	190	184	3.98**	189 (1596)
The Dalles Creek			188		193	187	0.89	189 (75)
Coefficient of Condition								
Big Springs Creek	0.772	0.746	0.734	0.744	0.734	0.756	0.84	0.743 (120)
Riggins					0.692			0.692 (20)
Little Goose Dam			0.674	0.749	0.689	0.705	2.80*	0.699 (220)
Ice Harbor Dam			0.678		0.654	0.693	6.32**	0.668 (90)
The Dalles Dam			0.704		0.668	0.687	3.68*	0.668 (75)
NaK-ATPase Activity								
Big Springs Creek	9.6	11.6		18.6		14.7	6.97**	13.6 (30)
Riggins					18.6			18.6 (8)
Little Goose Dam			13.9	18.0	19.0	13.6	2.41*	16.1 (32)
Ice Harbor Dam					19.5	14.6	5.88*	17.1 (16)
The Dalles Dam					17.6	15.9	0.70	16.8 (16)
Saltwater Tolerance[c]								
Big Springs Creek		40.5(5)		0(2)		0(0)		
Riggins								
Little Goose Dam		40.3(3)		5(1)				
Ice Harbor Dam		71(4)		5(1)				

[a] Appearance was expressed as a percentage of fish with smolt and intermediate appearance.

[b] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

[c] Percentage survival with median survival time in parentheses.

variations in the physical and biological environment as related directly or indirectly to growth, and seasonal physiological changes such as sexual maturation or parr-smolt transformation.

NaK-ATPase Activity

The gills of fish play an important role in the maintenance of proper salt and water balance (Parry 1966, Maetz 1971). In freshwater, fish take in water and lose salts via the gills, while in seawater the situation is reversed, fish lose water across the gills and concentrate salts. To counteract this, saltwater fish must drink seawater to prevent dehydration. The excess salts that accumulate must be transported across the gills against a chemical gradient (seawater contains more salts than the body fluids of fish in saltwater). This active transport of salts requires energy. The energy for the transport is derived from adenosine triphosphate (ATP) via the enzyme, adenosine triphosphatases (ATPase), or more specifically Na^+, K^+ - stimulated ATPase (NaK-ATPase) (Parry 1960, Bonting and Caravaggio 1963, Potts 1968, Maetz 1971). The enzyme NaK-ATPase increases when anadromous fishes become adapted to a saltwater environment (Epstein et al. 1967, Kamiya and Utida 1969, Zaugg and McLain 1969 and 1970). A twofold increase in activity during parr-smolt transformation and a corresponding decrease in activity during the desmoltification stage have been reported (Zaugg and McLain 1970 and 1972, Adams et al. 1973, Zaugg and Wagner 1973). The elevation in NaK-ATPase activity during parr-smolt transformation have been correlated with increased saltwater survival (Adams et al. 1975, Zaugg and Wagner 1973).

In studies of winter and summer steelhead trout, an increase in gill NaK-ATPase activity, associated with parr-smolt transformation, preceeded seaward migration (Zaugg and McLain 1972, Adams et al. 1973, Zaugg and Wagner 1973). NaK-ATPase activity decreased and the percentage of fish which migrated declined when steelhead were subjected to temperatures of 13 C or higher, or when the length of increasing photoperiod approximated that of the summer solstice.

From a comparison of NaK-ATPase values of wild steelhead trout smolts and non-smolting mature males (Fig. 8A), we believe that fish with activity values above 10 (μ moles of ATP hydrolyzed/hr per mg protein) were undergoing parr-smolt transformation. Migrating, wild steelhead trout collected in the Big Springs Creek weir and the dams had elevated NaK-ATPase activities (Fig. 8A and Table 7). The peak of activity occurred in May, which corresponded to the peak period of downstream migration of wild steelhead trout from Big Springs Creek and the upper Lemhi River. Zaugg and Wagner (1973) observed a similar NaK-ATPase activity pattern for wild winter steelhead trout from the Alsea River, Oregon, with NaK-ATPase activity somewhat elevated in March and April but reaching a peak in May. Wild rainbow-steelhead trout collected from Big Springs Creek in early July had no elevation in NaK-ATPase activity.

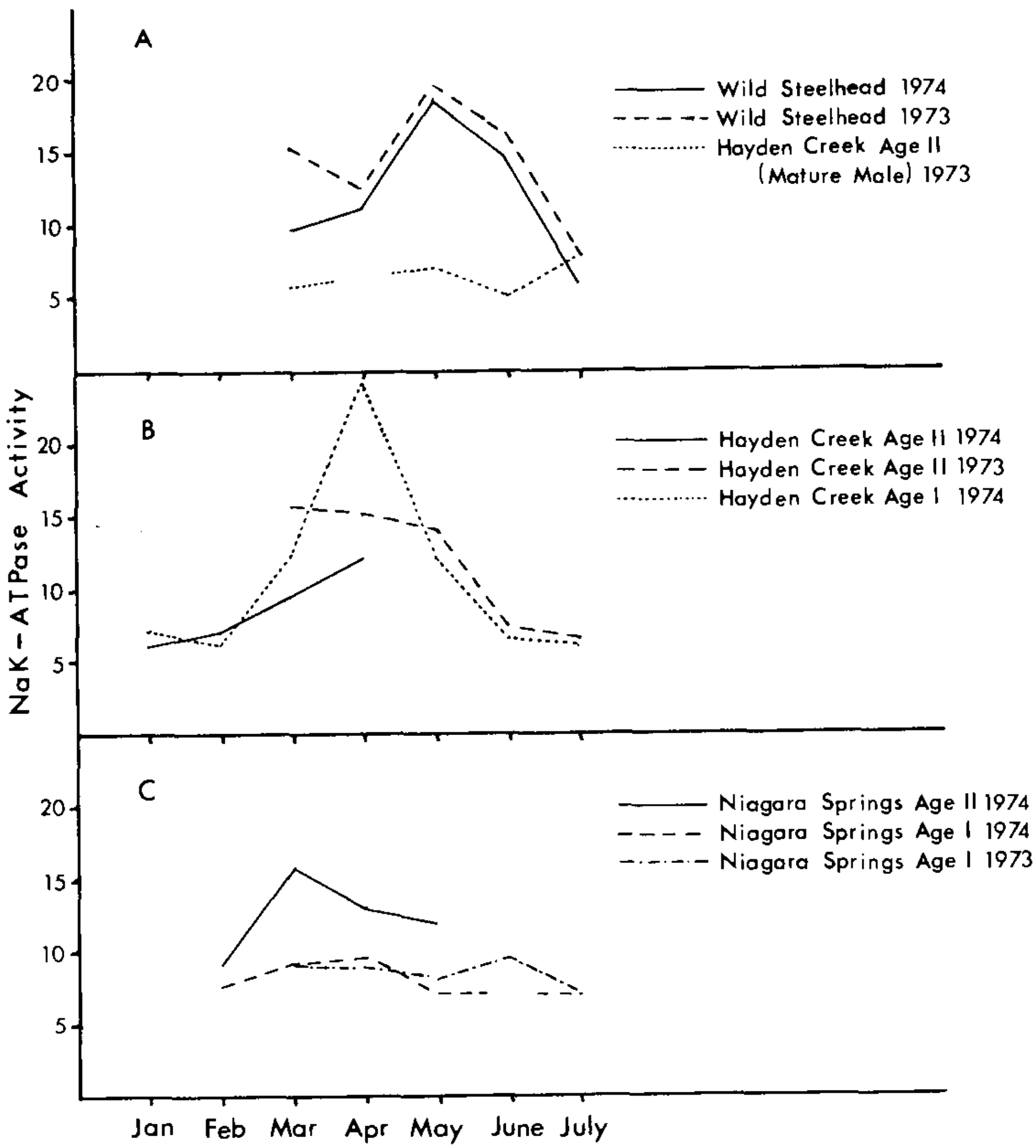

Figure 8. Seasonal changes in mean NaK-ATPase activity of wild (collected at the Big Springs Creek weir) and hatchery steelhead trout, 1973-74.

NaK-ATPase activity was elevated in wild steelhead trout collected from the Salmon, Snake, and Columbia rivers in 1974. NaK-ATPase activity levels in fish from Big Springs Creek were not significantly different from that in fish collected downstream at the dams (Fig. 7, Table 6).

The age I and age II steelhead trout from Hayden Creek Station and the age II fish from Pahsimeroi pond had increased activity the same as wild fish, but the peak occurred in March or April rather than May as in the wild fish (Fig. 8B and C). A decrease in the enzyme activity in hatchery fish occurred in May to a level similar to that observed in March (Table 8). The decreased activity in May might be an indication that some of the hatchery fish had started the desmoltification process. A similar May decrease in NaK-ATPase activity was observed in summer steelhead trout reared at the Skamania Fish Hatchery (Washougal River, Washington) by Adams et al. (1973).

Unlike the fish reared at Hayden Creek Station or from the Pahsimeroi pond, the age I steelhead trout reared at Niagara Springs Hatchery or the precocious mature males from the Hayden Creek Station did not have elevated NaK-ATPase activity at anytime (Fig. 8A and C, Table 8). The relatively warm (15 C) constant temperature water used at Niagara Springs hatchery might have been the reason for no increase in NaK-ATPase activity. Adams et al. (1973) observed no increase in NaK-ATPase activity of summer steelhead trout reared in constant temperature water of 15 or 20 C. The lack of a seasonal increase in NaK-ATPase activity leads us to conclude that few steelhead trout reared at the Niagara Springs Hatchery complete that part of their parr-smolt transformation while at the hatchery. Large numbers of the steelhead trout reared at Niagara Springs Hatchery and released into the Pahsimeroi River migrated seaward, thus the ATPase activity increased after they were released into the river or elevated ATPase activity was not necessary for them to start their seaward migration. Many Niagara Springs steelhead did not migrate seaward until after the normal migration period, a possible effect of the warmer water at Niagara Springs Hatchery. Zaugg and Wagner (1973) reported reduced NaK-ATPase activity and fewer fish migrating when steelhead trout were reared in 15 and 20 C water versus in colder water.

Saltwater Tolerance

Parr-smolt transformation of juvenile anadromous salmonids has often been associated with the development of systems for osmotic and ionic regulation. Survival in a marine environment requires a fully developed, functional hypo-osmoregulatory system. Parr-smolt transformation (including migration) and seawater adaptation, however, may be two distinct and unrelated physiological processes. The ability to survive in seawater is partly a function of size (Parry 1958 and 1960, Houston 1961, Conte and Wagner 1965, Conte et al. 1966, Weisbart 1968, Wagner et al. 1969, Wagner 1974b).

Table 8. Mean NaK-ATPase activity of wild steelhead trout collected at the Big Springs Creek weir and hatchery steelhead trout at Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery 1973-74. NaK-ATPase activity is expressed as μ moles of ATP hydrolyzed/hr per mg protein. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

Release group	NaK-ATPase Activity							F
	Jan	Feb	March	April	May	June	July	
Wild steelhead 1974			9.6	11.3	18.6	14.7	6.1	13.58**[a]
Wild steelhead 1973			15.1	12.5	19.4	16.1	8.1	7.58**
Hayden Creek age II 1973 (mature males)			5.3		7.0	4.9	7.7	3.25*
Hayden Creek age II 1974	6.3	6.8	9.6	12.2				13.27**
Hayden Creek age II 1973			15.6	15.0	14.0	7.7	6.3	3.25*
Hayden Creek age I 1974	6.8	6.3	11.8	24.9	12.0	6.8	6.1	37.62**
Niagara-Pahsimeroi age II 1974		9.2	15.7	13.2	12.2			1.85
Niagara Springs age I 1974		7.3	9.0	9.6	7.0	---	6.8	1.64
Niagara Springs age I 1973			8.8	9.0	8.2	9.5	7.2	.92

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Although salmon and trout can be acclimated to seawater before parr-smolt transformation (Parry 1958, Wagner et al. 1969, Kepshire and McNeil 1972, Giger 1972, Murai and Andrews 1972, Wagner 1974b), the development of the hypo-osmoregulatory mechanism appears linked to other physiological changes that occur during parr-smolt transformation. Adams et al. (1975) observed an increase in saltwater survival and NaK-ATPase activity at the onset of parr-smolt transformation in steelhead trout. Conte and Wagner (1965) and Adams et al. (1975) provide data for steelhead trout that indicates the saltwater resistance was transient and if the fish were retained in freshwater after the usual time of migration, they lose their ability to live in saltwater. The post-smolt decline in seawater tolerance has also been observed in coho and sockeye salmon (Baggerman 1960, McInerney 1964, Adams et al. 1973).

In the summer steelhead trout we studied, seawater survival was never high, but fish tested in March and April survived better than fish tested earlier or later in the season (Table 9). Juvenile steelhead trout were more euryhaline prior to the migration period (March-April) than during the peak of migration. All of our test fish became steno-haline for freshwater by the time migration from the upriver areas had terminated in early June.

Saltwater survival appeared to be similar for fish from the same hatchery, but varied for fish from the different hatcheries and the wild steelhead trout. The mature males were least able to survive the immediate transfer from freshwater to saltwater and usually died within 8-12 hours. Few of the steelhead trout from the Niagara Springs Hatchery were able to tolerate the transfer to saltwater. Wild steelhead trout survived better in saltwater than the hatchery fish.

The low saltwater survival we observed may have been affected by the transportation and handling necessary in our tests. Handling may have increased mortality through the phenomenon known as "osmotic" or "laboratory diuresis" or other conditions of electrolyte imbalance (Forster and Berglund 1956, Houston 1961). Fish reared under different conditions may have reacted differently to the handling stress we imposed on the fish. The presence of *trichadina* and Hagerman redmouth disease in age I and II steelhead from Hayden Creek Station in 1974 may have affected their ability to survive in saltwater.

Behavior of steelhead when placed in saltwater provided a clue to the probability of survival. When first introduced into saltwater, many steelhead trout swam rapidly around the tank, gasped for air, and had a tendency to jump out of the holding tank. Fish which were not going to survive in saltwater turned dark and swam in a whirl or horizontal spiral several hours prior to death. Fish then became moribund and would rise to the surface with a series of gulping reflexes, as if in respiratory difficulty. Fish which remained in this state usually died within a few hours. Conte and Wagner (1965) speculated that the salt-water death results from an imperfect circulatory system. Impairment of the blood flow would lead to other effects on vital organs, such as impairment of the excretory system (kidney and gills) with subsequent effect on acid-base balance. Major changes in the solute composition of

Table 9. Percentage survival and median survival time (days in parentheses) of wild (collected from the Big Springs Creek weir) and hatchery steelhead trout (from Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery) exposed to saltwater (30 ppt) for 10 days, 1973-74.

Group	Jan	Feb	March	April	May	June	July
Wild steelhead 1974				40(5)	0(2)	0(0)	0(0)
Wild steelhead 1973					10(2)	0(1)	0(1)
Hayden Creek age II 1973 (mature males)			0(1)		0(1)	0(0)	0(0)
Hayden Creek age II 1974	0(0)	0(0)	0(0)	0(0)			
Hayden Creek age II 1973			23(2)		0(2)	0(0)	0(0)
Hayden Creek age I 1974	0(0)	0(0)	15(1)	10(0)	0(0)	0(0)	
Niagara-Pahsimeroi age II 1974			20(4)	25(4)	0(2)		
Niagara Springs age I 1974		0(0)	0(0)	0(1)	0(1)	0(0)	
Niagara Springs age I 1973			3(2)		0(2)	0(1)	0(0)

the blood occur when fish enter saltwater and this has a direct effect on the acid-base balance of the fish (Houston 1959, Parry 1960, Gorden 1959).

Migratory Behavior

The migratory behavior of juvenile summer steelhead trout has been studied in a number of upper Columbia River drainages (Keating 1958, Bell 1959 and 1960, French and Wahle 1959, Chapman and Bjornn 1969) and in the mainstem of the Snake and Columbia rivers (Mains and Smith 1956, Raymond 1967 and 1969a, Raymond et al. 1974 and 1975, Sims 1970). Juvenile steelhead trout in Idaho migrate downstream primarily as (1) subyearlings in the fall, winter, or spring after their first summer, (2) yearlings in the fall after their second summer, and (3) smolts in the spring of their third or fourth year (Bjornn 1966). The subyearling and yearling trout may move downstream many kilometers, but stop before reaching the sea.

Hoar (1958) argued that seaward migration of salmonids was not purely fortuitous and undirected and that internal motivation responding to external factors are important. Steelhead trout migrate only when they are in the proper physiological condition (undergone parr-smolt transformation) and at a time when the appropriate external stimuli are present (Baggerman 1960). The possible environmental factors involved in seaward migration have been divided into two groups, "primers" and "releasers" by Hoar (1953) and Baggerman (1960). Priming factors prepare the fish for migration and might be external or internal in nature. Priming factors result in a slow change in behavior. Releasing factors are appropriate external stimuli that act over a short period of time and initiate migration once the preparatory phase is complete. External factors which may act as releasers are temperature, light intensity, river discharge, and meteorological factors (Baggerman 1960).

Wild Steelhead Trout

Wild rainbow-steelhead trout moved downstream in Big Springs Creek and the upper Lemhi River throughout the year (Fig. 9). Rainbow-steelhead trout left Big Springs Creek primarily as three length-age groups: (1) subyearlings (60 - 120 mm long) left during the fall, winter, or spring after their first summer, (2) yearlings (140 - 210 mm long) left in the fall after their second summer, and (3) smolts (160 - 240 mm long - age II) migrated in the spring before their third summer. A few steelhead trout remained an additional year and migrated in the spring as age III smolts (Bjornn 1966). Wild rainbow-steelhead trout left the upper Lemhi River as (1) yearlings in the fall after two summers of rearing and (2) smolts in the spring after two summers in the stream (Fig. 9). In Big Springs Creek, subyearling migrants outnumbered the other age groups while at the Lemhi weir site, smolts migrating in the spring outnumbered all other groups. Few subyearlings migrated downstream past the Lemhi weir, even though large numbers were present in the river.

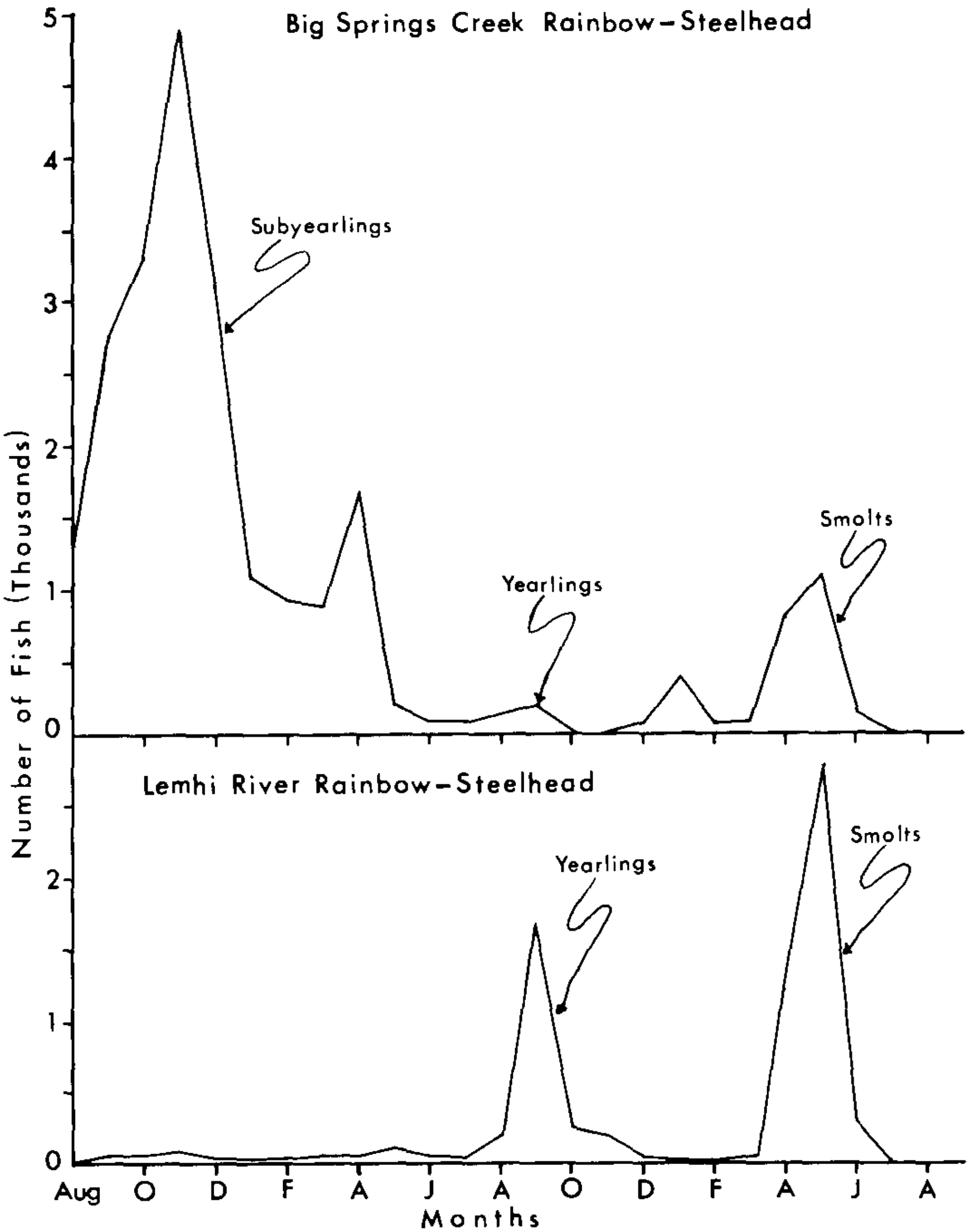

Figure 9. Number of rainbow-steelhead trout of 1972 year class that migrated past Big Springs Creek and Lemhi River weir sites.

We examined the daily catch records of wild rainbow-steelhead trout at the Big Springs Creek and Lemhi River weirs from 1970-72 to determine the pattern, timing, and duration of the seaward migration. We classified rainbow-steelhead trout captured at the weirs as steelhead smolts if they were longer than 150 mm.

The 1973 and 1974 seaward migration of wild smolts was similar to the migration patterns in earlier years (Fig. 10). Each spring wild steelhead trout started migrating in mid-April and continued till the first of June. The median migration date from Big Springs Creek (date when 50% of the migrants had passed the weir site) varied from May 4 in 1970 to May 13 in 1973 (Table 10), and the average median migration date was May 8 (five year average, 1970-74). The duration of the wild steelhead smolt migration (the number of days between capture of 10% and 90% of the migrants) varied from 36 to 57 days, with a five year average of 47 days (Table 10).

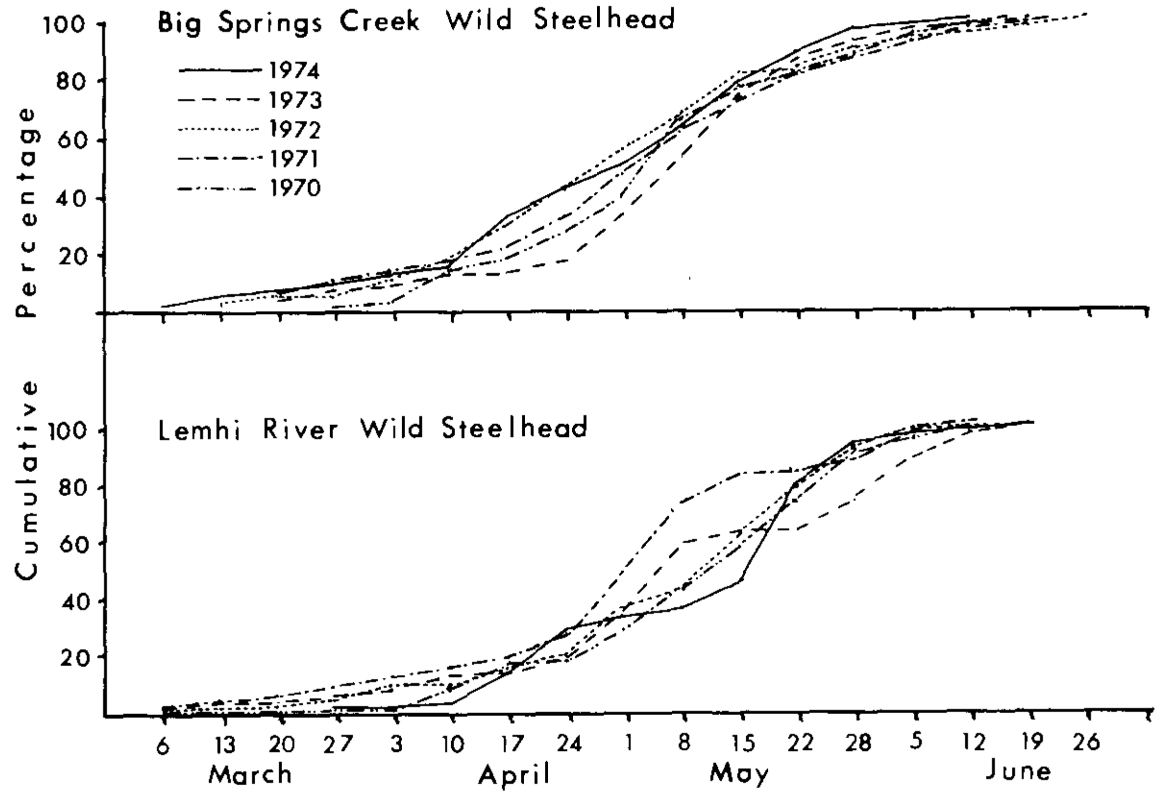

Figure 10. Cumulative catch curves of seaward migrating wild steelhead trout collected at the Big Springs Creek and Lemhi River weirs, 1970-1974.

Table 10. Date of peak catch, median migration date (date on which 50% of the migrants had passed the recovery site), and duration (number of days between capture of 10% and 90% of the migrants) of seaward migration of wild steelhead trout collected at the Big Springs Creek and Lemhi River weir, 1970-74.

	Big Springs Creek			Lemhi River		
Year	Peak catch	Median migration date	Duration	Peak catch	Median migration date	Duration
1970	5/3	5/4	54	5/28	5/15	50
1971	5/14	5/11	57	5/8	5/7	49
1972	5/8	5/5	49	5/20	5/19	39
1973	5/7	5/13	36	5/8	5/11	48
1974	5/14	5/8	40	5/22	5/28	39
5 year average	5/9	5/8	47	5/15	5/15	45

The wild smolt migration in 1973 occurred primarily during May in Big Springs Creek and from early May to mid-June in the Lemhi River (Fig. 11). The small number of smolts leaving Big Springs Creek in April resulted in a later than usual timing and a shorter than usual duration. The timing and duration of the wild smolt migration past the Lemhi River weir site in 1973 was within the range observed in other years (Table 10). Nevertheless, the migration pattern was unusual because few fish migrated during April or the latter half of May, while an unusually large number migrated in June. The less than average river discharge in 1973 from a record low snowpack and cooler than average weather in April may have retarded the migration of the smolts.

In 1974, wild steelhead trout migrated from Big Springs Creek and the upper Lemhi River from mid-April to the first of June (Fig. 11). The timing and duration of the migration past the Big Springs Creek and the Lemhi River weir sites was similar to the timing and duration observed in previous years (Table 10). The large river discharge in 1974 from a record snowpack and warm weather in April provided favorable conditions for migration of smolts.

Wild steelhead trout smolts captured at the weirs, tagged and released April 28, 1974 upstream in Big Springs Creek moved out of the creek rapidly (Fig. 12) with 50% of the migrants passing the weir site within 2 days of release (Table 11). We recaptured a larger percentage of the wild migrants than of all but one of the hatchery groups released in Big Springs Creek (Table 12). We estimate that only 5% $\pm$ 1% of the tagged wild smolts were still present in Big Springs Creek by July when we sampled the stream with electrofishing gear.

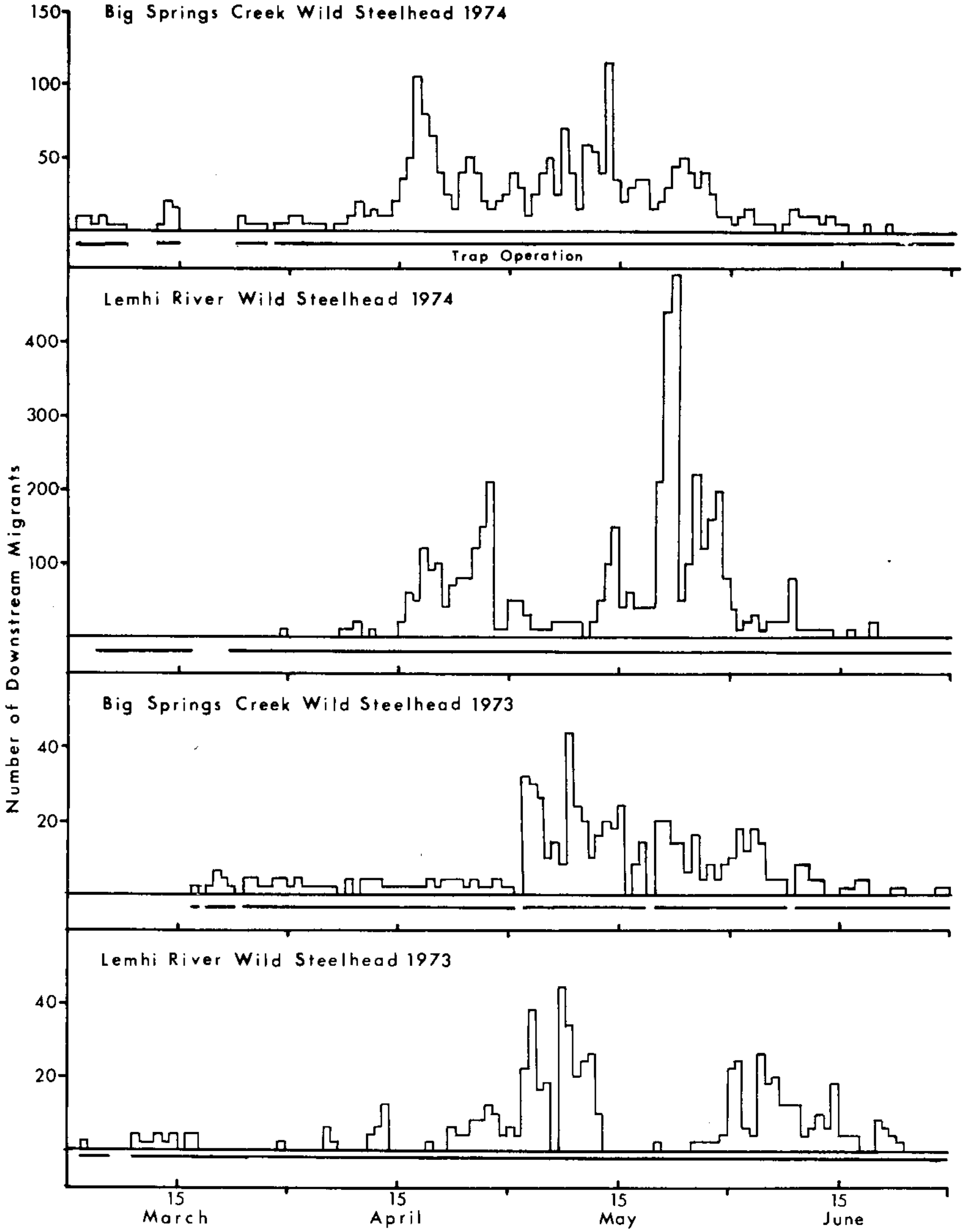

Figure 11. Days of trap operation and daily catch of seaward migrating wild steelhead trout smolts (longer than 150 mm total length) at the Big Springs Creek and Lemhi River weirs, 1973-1974.

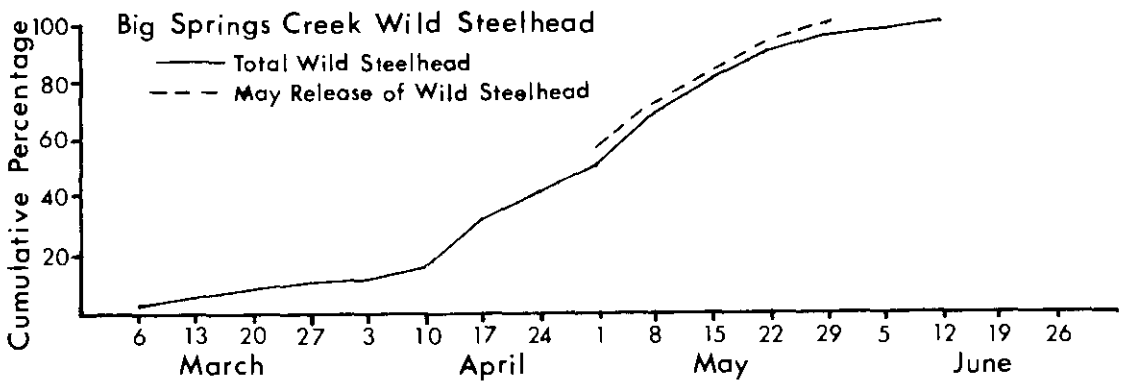

Figure 12. Cumulative catch curves of seaward migrating wild steelhead trout (total and May release group) collected at the Big Springs Creek weir, 1974.

Table 11. Migration statistics of wild steelhead trout captured at the Big Springs Creek weir, tagged and released upstream in Big Springs Creek, and then recaptured at the Big Springs Creek weir during 1974, including release date, number released, percentage recovered, median migration date (date on which 50% of the migrants had passed the recovery site), median migration days (number of days between release and date when 50% of the migrants had passed the recovery site), duration (number of days between recovery of 10% and 90% of the migrants), mean days out (average number of days between release and migration past the recovery site), residual index (estimated percentage of release group remaining in Big Springs Creek after the migration period).

	Wild steelhead trout
Release date	4/28
Number released	184
Percentage recovered (total)	39
(1-15 days)	32
(1-30 days)	39
(before 6/1)	39
Median migration date	4/30
Median migration days	2
Duration (days)	18
Mean days out	7
Residual index (%)	5

Table 12. Total percentage recovery and percentage recovery in first 15 days after release (in parentheses) of tagged wild steelhead trout and hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973 and 1974.

Release group	Released the first of: March	April	May	June
Wild steelhead 1974			39(32)	
Hayden Creek age II 1973 (Mature male)		2(0)	1(0)	2(1)
Hayden Creek age II 1974	15(3)	33(8)		
Hayden Creek age II 1973		25(2)	12(6)	6(6)
Hayden Creek age I 1974	16(4)	17(17)	43(19)	24(24)
Niagara - Pahsimeroi age II 1974		32(13)		
Niagara Springs age I 1974	7(2)	10(3)	12(2)	
Niagara Springs age I 1974 (large)	7(2)	18(6)	21(10)	21(10)
Niagara Springs age I 1973		13(6)	22(6)	15(9)

Seaward migration of wild steelhead trout smolts through the lower Snake and Columbia rivers occurs only during the spring (Mains and Smith 1956, Raymond 1967 and 1969a) and generally coincided with the snow melt runoff during May (Raymond et al. 1975). The median migration date of the wild and hatchery steelhead trout migration, varied from May 8 (1971) to May 25 (1970), with a 5 year average of May 17 (Ebel et al. 1975). The duration of migration, calculated as the number of days between dates when 10% and 90% of the smolts migrate downstream, averaged 28 days at Ice Harbor Dam (Table 13).

Table 13. Date of peak catch, median migration date, and duration of seaward migration of steelhead trout (wild and hatchery) collected at the Ice Harbor Dam, 1970-74.

Year	Ice Harbor Dam: Peak catch	Median migration date	Duration
1974	5/13	5/13	35
1973	5/24	5/24	25
1972	5/21	5/22	25
1971	--	5/8	--
1970	--	5/25	--
3 or 5 year average	5/20	5/17	28

Steelhead trout migrated past Ice Harbor Dam mainly during late May and early June in 1973 compared to mostly during May in 1974 (Fig. 13). Peak catches of steelhead trout in 1973 were made on May 30 at Little Goose Dam, May 24 at Ice Harbor Dam, and June 3 at the Dalles Dam, later than in most other years (Fig. 14).

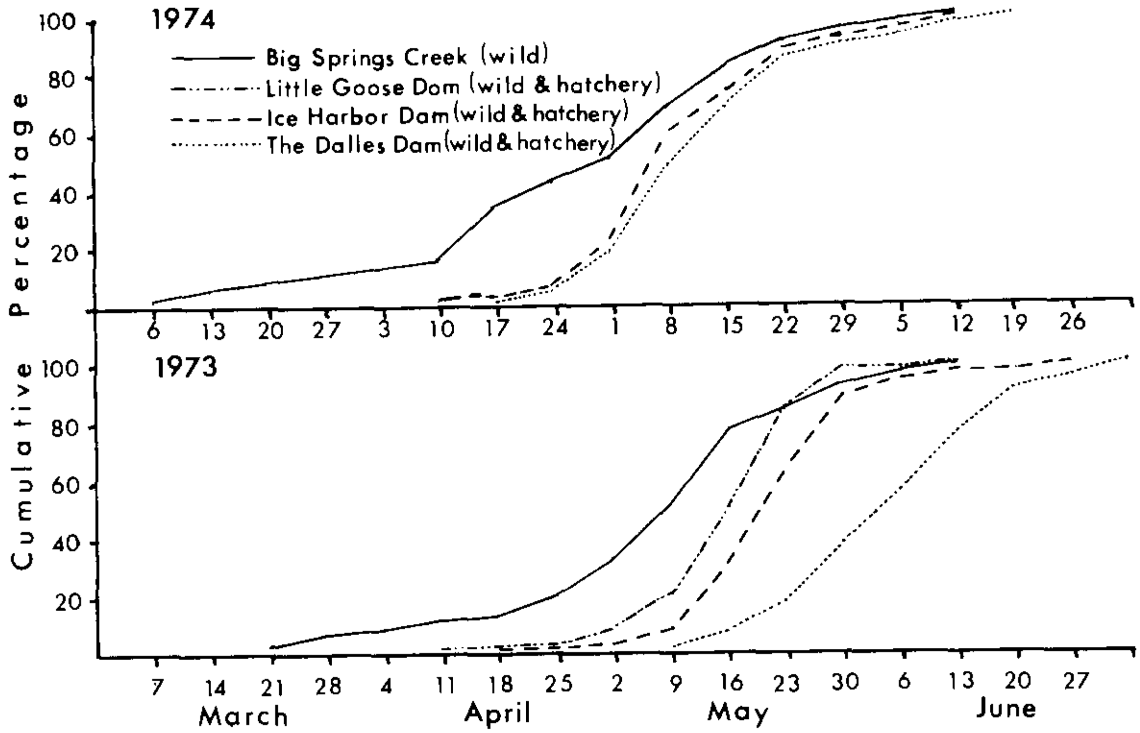

Figure 14. Cumulative catch curves of seaward migrating steelhead trout at the Big Springs Creek weir and at Little Goose, Ice Harbor, and The Dalles dams, 1973-74.

Raymond et al. (1975) estimated that seaward migrating steelhead trout in 1973 sustained a 95% loss from Little Goose Dam to the Dalles Dam. The high mortality was attributed to passage of most fish through the turbines, predation, and delay in migration. During the record low flow of 1973, most of the river discharge passed through the powerhouses. Only minimal spilling occurred at the Snake River dams and none at the Columbia River dams. As a consequence, most of the migrating steelhead smolts were subjected to turbine-related mortality. Raymond et al. (1974) reported large populations of squawfish located in the tailrace below the dams and in the reservoirs of the Snake River in 1973.

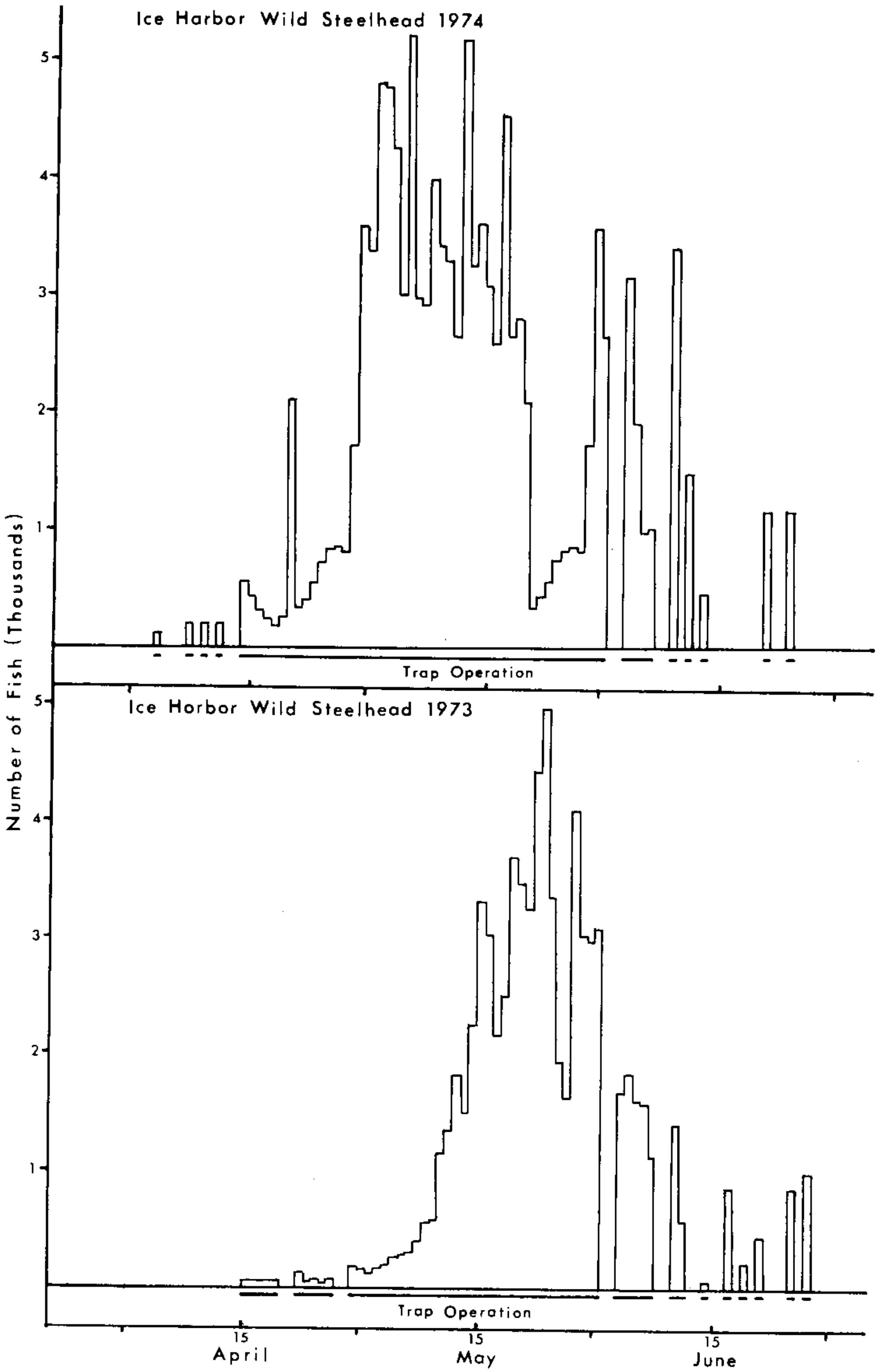

Figure 13. Days of trap operation and daily catch of seaward migrating steelhead trout (wild and hatchery) at Ice Harbor Dam, 1973-74.

The apparent high loss of smolts in 1973 may not all have been mortality. Larger than normal numbers of smolts failed to complete their seaward migration because low river discharges and reduced velocities in the reservoirs delayed migration. Raymond et al. (1974) reported a significant increase in the abundance of holdover steelhead trout in the Snake and Columbia river reservoirs in 1973. Large numbers of steelhead trout were collected in purse seines in Lower Monumental, Little Goose and John Day reservoirs in the summer and fall of 1973. Few of the holdover smolts resumed their migration the following spring, however, indicating they either perished or residualized (Raymond et al. 1975).

Travel time or migration rate of downstream migrating steelhead trout is related to river discharge and velocity, the larger the discharge the faster velocity and the rate of fish migration. Raymond (1968 and 1969b) determined that juvenile chinook salmon moved only one-third as fast through McNary and John Day reservoirs as through free-flowing stretches of river. Similar delays in impoundments in the Snake River were found by Bentley and Raymond (1975). Raymond et al. (1975) gave chinook and steelhead migration rates in free-flowing sections of the river ranging up to 59.7km/day and up to 24.2km/day in impounded sections (Table 14). Travel time from the Lemhi or Pahsimeroi Rivers to the estuary, based on the migration rates in Table 14 would range from 35 to 94 days. Raymond et al. (1975) estimated that steelhead trout migrating from the Salmon River at Riggins during a year with low flows would require 78 days to reach the estuary; arriving there about 40 days later than with high flows or before dams were constructed. The effect of this change in the timing of steelhead trout migration on survival is not known.

Table 14. Estimated days[a] for steelhead trout to travel from the Hayden Creek Station or Pahsimeroi River release site to the Columbia River estuary.

	Flow[b]		
	Low	Moderate	High
Pahsimeroi or Lemhi Rivers to Riggins	16	9	7
Riggins to Little Goose Dam	23	14	8
Little Goose to Ice Harbor Dam	13	8	4
Ice Harbor to The Dalles Dam	29	18	10
The Dalles to estuary	13	8	6
Pahsimeroi or Lemhi Rivers to estuary	94	57	35

[a]Travel time based on migration rates presented by Raymond et al. (1975)

	Low	Moderate	High
free-flowing	24.2 km/day	40.2 km/day	54.7 km/day
impounded	8.1 km/day	12.9 km/day	24.2 km/day

[b]Low flow: Snake River, 30-50,000 cfs; Columbia River, 150-180,000 cfs
Med flow: Snake River, 80-100,000 cfs; Columbia River, 200-300,000 cfs
High flow: Snake River, 120-180,000 cfs; Columbia River, 350-500,000 cfs

Most steelhead trout migrated downstream during the night or at twilight. Bjornn (1966) reported that migration occurred almost entirely during the hours of darkness and rarely did fish enter the Big Springs Creek trap during the hours of daylight. Mains and Smith (1956), in free flowing sections of the Snake and Columbia rivers, and Long (1968a) at The Dalles Dam collected more steelhead trout at night than during the day.

Hatchery steelhead trout

The time of seaward migration of hatchery fish was similar to that of wild fish in that most fish were recaptured from mid-April to mid-June. The pattern and timing of migration differed between test groups (Figs. 15-17, and Table 15). Only 1-2% of the precociously mature male steelhead trout released into Big Springs Creek in 1973 were recaptured at the weir, substantiating the belief that mature males do not become smolts and migrate.

The fish from Hayden Creek Station and Pahsimeroi pond had the largest percentage migrating out of Big Springs Creek (Table 12). Hayden Creek age I and age II and Niagara - Pahsimeroi age II fish released in April or May had the largest percentage of migrants. The high percentage migrating and rapid migration out of Big Springs Creek of the fish from Hayden Creek Station and Pahsimeroi pond was an indication that most of those fish had undergone parr-smolt transformation.

Fewer of the fish from Niagara Springs Hatchery migrated and they took longer than fish from Hayden Creek Station or the Pahsimeroi pond (Table 12). The timing of migration of Niagara Springs fish released in April or May was later than that observed for other hatchery steelhead trout released at the same time (Fig. 16 and 17). Few of the Niagara Springs age I fish released in April and May had completed the parr-smolt transformation and were ready to migrate when released. The Niagara Springs age I large steelhead trout released in 1974 had more migrants with less delay, indicating the importance of size in the parr-smolt transformation. Test fish from Hayden Creek Station and the Pahsimeroi pond (Niagara - Pahsimeroi age II) released in early April migrated soon after release. Hayden Creek age II steelhead trout in 1973 and age I steelhead trout in 1974, and Niagara - Pahsimeroi age II steelhead trout in 1974 moved within the first month after release and migrated ahead of the wild steelhead trout from Big Springs Creek (Fig. 18). Hayden Creek age II steelhead trout released in 1974 migrated at the same time as the wild fish and were not plotted in Fig. 18. The median migration date of these test groups varied from April 14 to April 29 (Table 15).

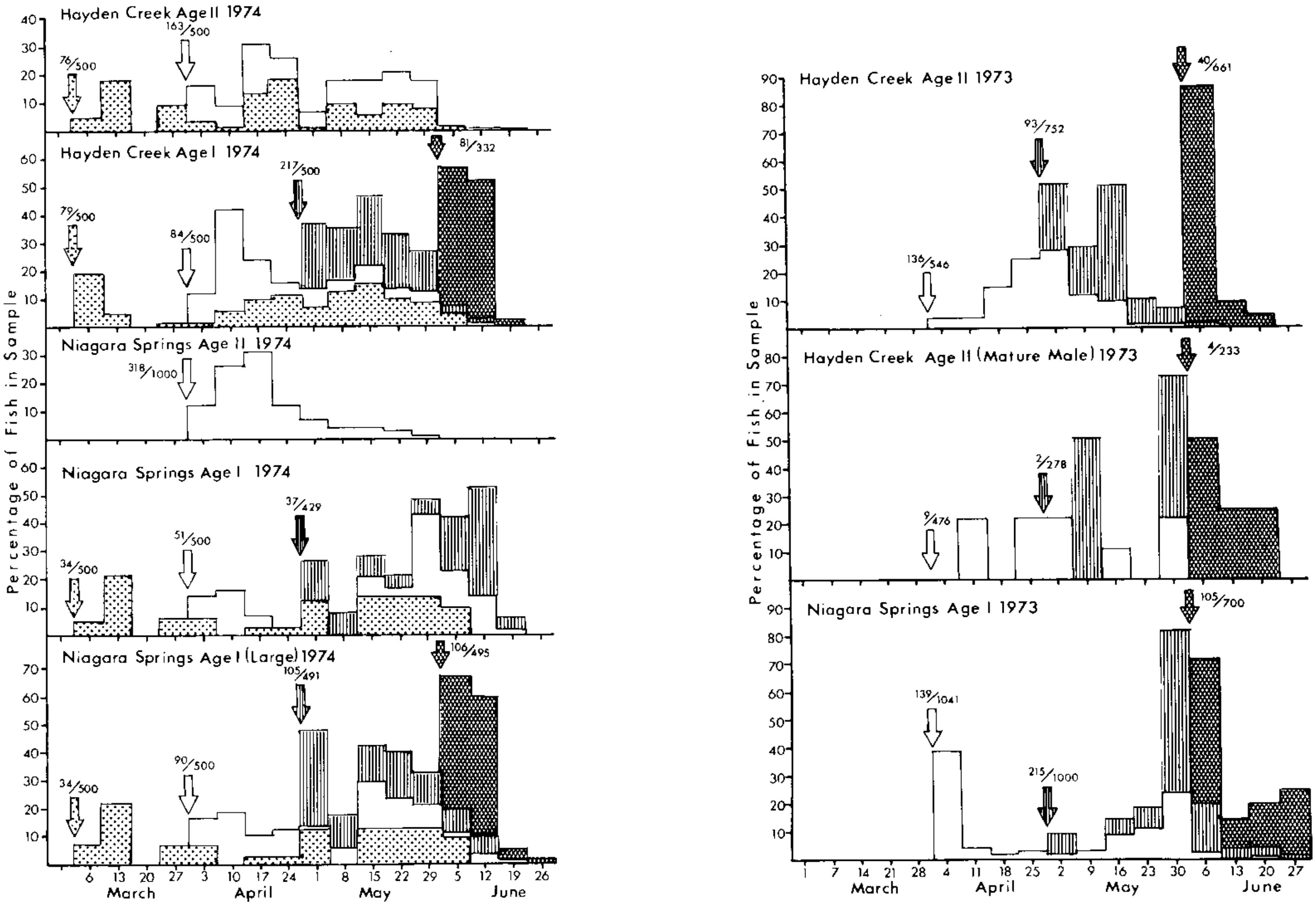

Figure 15. Pattern and magnitude of migration of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1974. Ratios above the arrows (date of release) are the number of fish recaptured/number of fish released in each group.

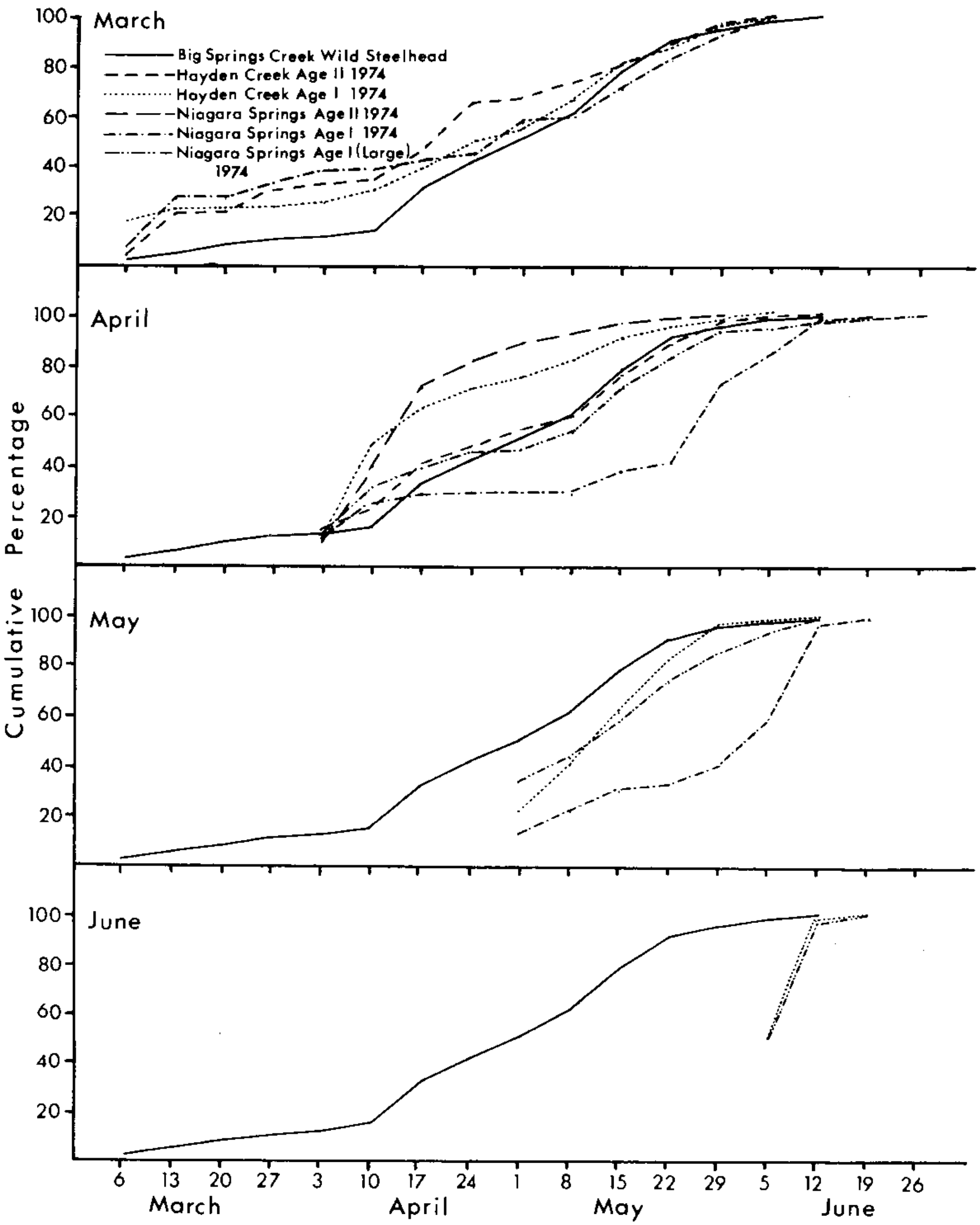

Figure 16. Cumulative catch curves of seaward migrating hatchery steelhead trout released into Big Springs Creek March-June and recaptured at the weir, 1974.

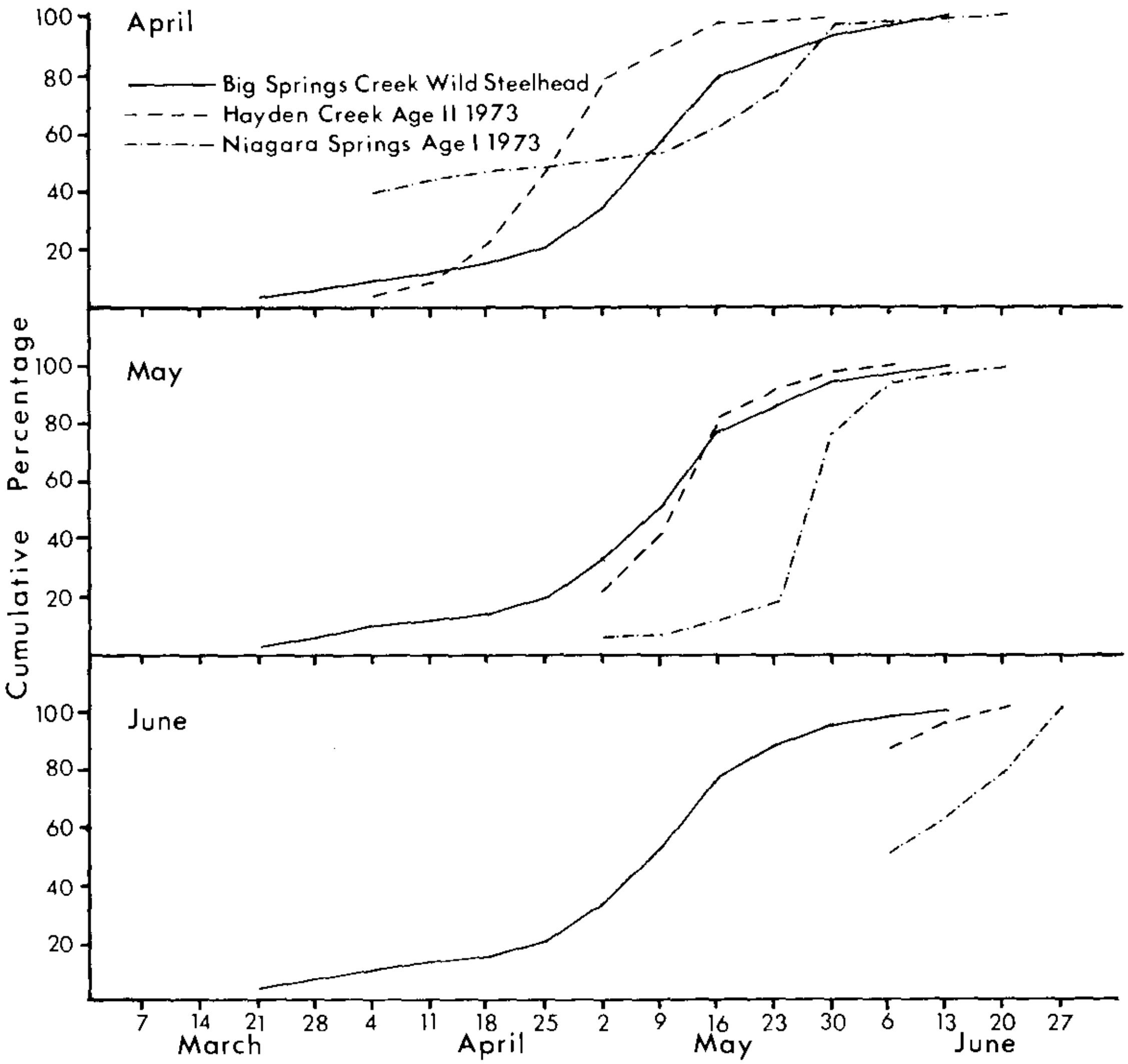

Figure 17. Cumulative catch curves of seaward migrating hatchery steelhead trout released into Big Springs Creek April-June and recaptured at the weir, 1973.

Table 15. Migration statistics of hatchery steelhead trout released into Big Springs Creek near the first of March, April, May, or June and recaptured at the weir, 1973-74, including release date, number released, percentage recovered, median migration date, median migration days, duration, mean days out, and residual index.

Release group	Release date	Number released	Percentage recovered: Total	1-15 days	1-30 days	Before June 1	Median migration date	Median migration days	Duration (days)	Mean days out	Residual index (%)
Hayden Creek age II 1974-March	3/2	500	15	3	5	15	4/21	50	74	48	3
-April	3/30	500	33	8	17	32	4/29	30	53	32	12
Hayden Creek age I 1974 -March	3/2	500	16	4	5	15	4/29	58	80	52	—
-April	3/31	500	17	9	12	17	4/14	14	47	22	--
-May	4/28	500	43	19	39	41	5/14	16	28	17	41
-June	6/1	500	24	24	24	--	6/8	7	9	8	49
Hayden Creek age II 1973-April	4/1	546	25	2	16	25	4/29	28	25	28	10
-May	4/28	752	12	6	12	12	5/14	16	25	15	21
-June	6/3	661	6	6	--	—	6/4	1	7	3	33
Hayden Creek age II 1973-April (mature males)	4/1	476	2				4/28	27	47	32	14
-May	4/28	278	1				5/10	12	17	21	14
-June	6/3	233	2				6/27	9	19	12	12
Niagara-Pahsimeroi age II 1974-April	3/30	1000	32	13	27	32	4/18	19	32	21	14
Niagara Springs age I 1974 -March	3/2	500	7	2	2	6	5/1	60	78	53	--
-April	3/30	500	10	3	5	7	5/27	58	66	48	5
-May	4/27	429	12	2	3	9	6/5	39	40	32	14
Niagara Springs age I large 1974 -March	3/2	500	7	2	2	6	5/1	60	78	53	—
-April	3/30	500	18	6	8	17	5/10	41	50	35	2
-May	4/27	491	21	10	17	18	5/13	16	36	18	23
-June	6/1	495	21	21	21	--	6/9	8	10	8	60
Niagara Springs age I 1973 -April	3/31	1041	13	6	7	12	5/7	37	59	31	13
-May	4/28	1000	22	1	7	13	5/31	33	20	31	20
-June	6/2	700	15	9	15	--	6/7	5	24	10	31

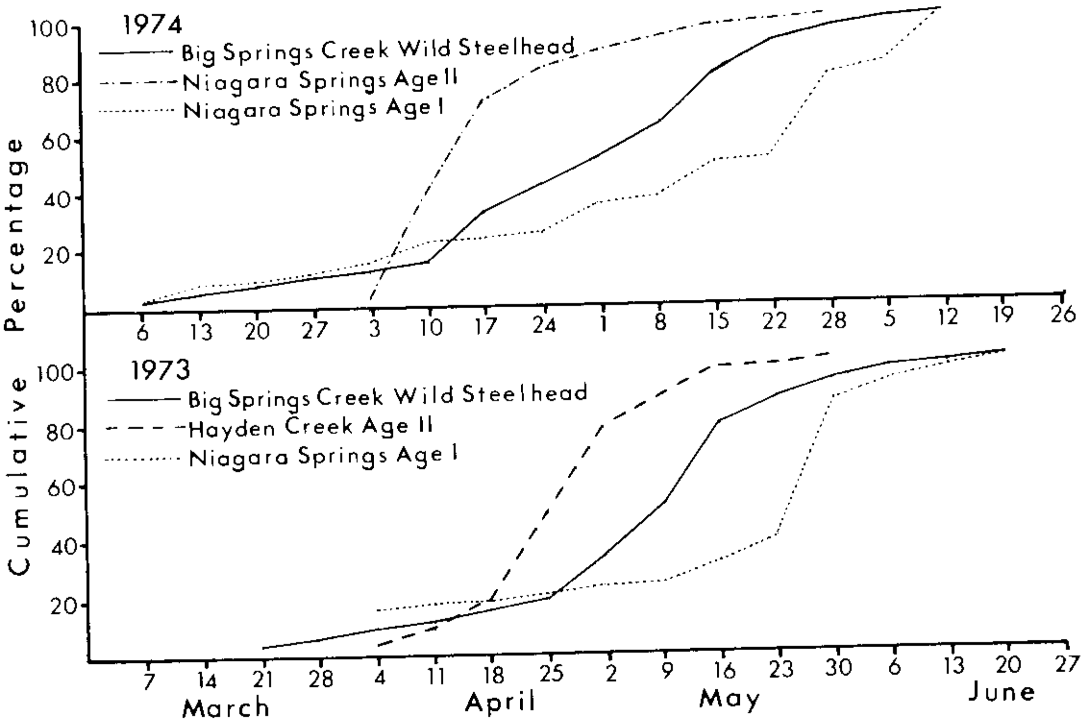

Figure 18. Cumulative catch curves of seaward migrating wild steelhead trout, age II hatchery fish from Hayden Creek Station or Niagara-Pahsimeroi ponds, and age I fish from Niagara Springs Hatchery, 1973 and 1974.

Steelhead trout from Niagara Springs Hatchery are normally released into the Pahsimeroi River from the first of March through mid-May (Reingold 1974 and 1975b). We evaluated the seaward migration of typical steelhead trout produced at Niagara Springs Hatchery by combining data for the test groups released in April and May in 1973 and in March, April, and May in 1974.

Age I steelhead trout from Niagara Springs Hatchery migrated later than wild fish from Big Springs Creek or hatchery steelhead trout from the Hayden Creek Station or the Pahsimeroi pond (Fig. 18). In 1973 and 1974, the seaward migration of Niagara Springs age I fish was approximately two weeks behind the migration of wild steelhead and 4 - 6 weeks behind the Hayden Creek age I and age II and the Niagara - Pahsimeroi age II fish. In 1973, the Niagara Springs age I steelhead trout migrated from mid-May to the first week of June (Fig. 18) with the peak day of migration on May 31. The median migration date occurred 3 days earlier on May 28. In 1974, the largest number of Niagara Springs age I fish were collected during late May with 50% of the migrants having passed the Big Springs Creek weir on May 26 (Table 15).

Idaho Department of Fish and Game personnel marked and released three groups (20,000 fish each) of Niagara Springs age I steelhead into the Pahsimeroi River in 1974. They released the first group of fish

March 11, second group April 1-3, and the last group May 1-5 (Reingold 1975b). Department personnel monitored the migration of the marked fish from the Pahsimeroi River at the Burstedt Lane downstream migrant trap, located 17.7 km (11 miles) downstream from the release site. Niagara Springs Hatchery steelhead trout released in the Pahsimeroi River migrated earlier than fish released in Big Springs Creek (Fig. 19).

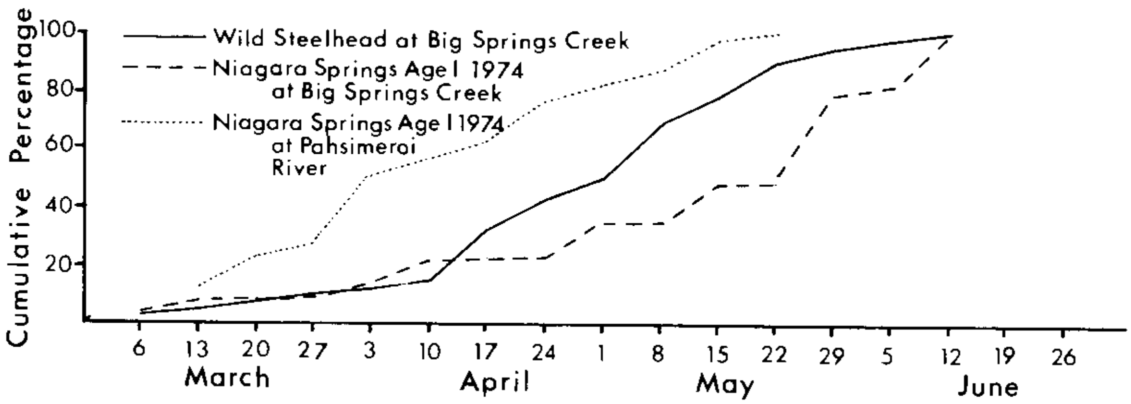

Figure 19. Cumulative catch curves of seaward migrating wild steelhead trout from Big Springs Creek, hatchery fish from Niagara Springs Hatchery released into Big Springs Creek and recaptured at the Big Springs Creek weir, and hatchery fish from Niagara Springs Hatchery released into the Pahsimeroi River and recaptured at the Burstedt Lane migrant trap on the Pahsimeroi River during 1974.

In early July of 1973 and 1974, we sampled Big Springs Creek with electrofishing gear to recapture tagged hatchery and wild steelhead trout which did not migrate to the sea. In 1973, we estimated that 1344 ± 353 hatchery steelhead trout (24 ± 6% of the age II fish, 13 ± 1% of the mature males and 20 ± 5% of the Niagara Springs age I fish) heldover or residualized in the creek (Table 16). Only 0.7% of the Hayden Creek age II steelhead and 1.3% of the Niagara Springs age I steelhead present in Big Springs Creek in July of 1973 migrated in the spring of 1974.

In July of 1974, we estimated that 15 ± 1% of the tagged steelhead trout released in 1974 and 3 ± 0.3% of the 1973 residuals were present in Big Springs Creek. We estimated that 8 ± 0% of the Hayden Creek age II fish, 20 ± 1% of the Hayden Creek age I fish, 14 ± 1% of the Niagara - Pahsimeroi age II fish, 6 ± 0% of the Niagara Springs age I fish, and 21 ± 1% of the Niagara Springs age I large steelhead trout were still in Big Springs Creek after the migratory period in 1974 (Table 16). Reingold (1968, 1969, and 1970) reported large numbers of steelhead trout from the Niagara Springs Hatchery remained in the Pahsimeroi River past the normal migratory period. About 4% of the adult steelhead trout returning to the Pahsimeroi River from the 1971 smolt release had remained an extra year in freshwater before entering the ocean (Reingold 1975b).

Table 16. Numbers and percentages of hatchery steelhead trout released in Big Springs Creek that migrated from the creek, residual fish present in the creek in July, and fish unaccounted for, 1973-74. The number of fish released minus the number of migrants minus the number of residual fish equals the number of fish unaccounted for.

				Residual fish			Fish unaccounted for	
Group of fish	Month released	Number released	Percentage migrating	Number recovered	Estimated number remaining	Estimated percentage remaining	Number	Percentage
Hayden Creek age II 1974	March	500	15	2	17 ± 2[a]	3 ± 0	407	81
	April	500	33	7	60 ± 4	12 ± 1	277	55
Hayden Creek age I 1974	March	500	16	0	------	------	421	84
	April	500	17	0	------	------	416	83
	May	500	43	24	205 ± 14	41 ± 3	78	16
	June	332	24	19	162 ± 11	49 ± 3	89	27
Niagara Pahsimeroi age II 1974	April	1000	32	17	145 ± 10	14 ± 1	537	54
Niagara Springs age I 1974	March	500	7	0	------	------	466	93
	April	500	10	3	26 ± 2	5 ± 0	423	85
	May	429	12	7	60 ± 4	14 ± 1	332	77
Niagara Springs age I 1974 large	March	500	7	0	------	------	466	93
	April	500	18	1	9 ± 1	2 ± 0	401	80
	May	491	21	13	111 ± 8	23 ± 2	275	56
	June	495	21	35	299 ± 21	60 ± 4	90	18
Hayden Creek age II 1973	April	54	0	0	------	------	54	100
	May	161	1	0	------	------	161	100
	June	215	1	1	9 ± 1	4 ± 0	206	96
Niagara Springs age I 1973	April	134	0	1	9 ± 1	7 ± 1	133	99
	May	202	3	0	------	------	196	97
	June	228	0	0	9 ± 1	4 ± 0	218	96
Hayden Creek age II 1973	April	546	25	5	54 ± 14	10 ± 3	356	65
	May	752	12	14	161 ± 42	21 ± 6	498	66
	June	661	6	19	215 ± 56	33 ± 8	406	61
Hayden Creek age II 1973 mature males	April	476	2	6	67 ± 18	14 ± 4	400	84
	May	278	1	4	40 ± 11	14 ± 4	236	85
	June	233	2	2	27 ± 7	12 ± 3	202	87
Niagara Springs age I 1973	April	1041	13	12	134 ± 35	13 ± 3	768	74
	May	1000	22	18	202 ± 53	20 ± 5	583	58
	June	700	15	20	228 ± 56	31 ± 8	367	52

[a] 95% confidence interval

No relationship between the percentage of each group recaptured as non-migrants by electrofishing and as migrants recaptured at the Big Springs Creek weir traps was apparent. Wagner (1970) observed an inverse relationship between the number of non-migrants remaining in the streams and the number of migrants.

Of the fish recovered by electrofishing in July of 1973, 23% were from those released in April, 36% from those in May, and 42% from those in June. In 1974, 1% of the fish recovered in July were from those released in March, 22% from those in April, 35% from those in May, and 42% from those in June. Since the fish released early did not migrate in large numbers and were least abundant in the July electrofishing samples, they must have died or been caught by anglers.

Fish which did not migrate stayed near the release site; 51% of the fish collected in 1973 and 63% in 1974 were recaptured just below the release site. Symons (1969) reported greater dispersal of wild compared to hatchery-reared Atlantic salmon (*Salmo salar*) when released into streams.

Large numbers of fish released into Big Springs Creek could not be accounted for as migrants or residuals (Table 16). Royal (1972) and Wagner[1/] reported similar findings for winter steelhead trout in Washington and Oregon. The fate of the fish not recovered at the weir or by electrofishing is unknown. Loss of tags, escapement past the weir, fish lost to angling, tagging and handling mortality, and natural mortality are all possible explanations for the loss of fish.

Hatchery trout usually do not survive as well as wild fish in streams (Miller 1958, Bams 1966, Fenderson et al. 1968, Symons 1969). Hatchery steelhead trout which do not migrate seaward shortly after release, are faced with two problems, finding food and finding a home. They must compete for both with resident trout and other hatchery fish.

The timing of migration of steelhead trout from Idaho hatcheries through the lower Snake River was usually later than the wild fish except in 1973 (Fig. 20). Except in 1973, most steelhead trout from the Hayden Creek Station, Niagara Springs Hatchery, and the Pahsimeroi pond migrated past Ice Harbor Dam during the last 2 - 3 weeks of May (Table 17). In 1973, the earlier timing of migration of the marked hatchery fish collected at Ice Harbor Dam was biased toward earlier and/or faster migrating fish. During low flow years, such as 1973, the migration timing of the hatchery fish should have been later like the wild fish (Fig. 20) rather than earlier.

[1/] Personal communications: H. H. Wagner, Oregon State Game Commission, Corvallis, Oregon.

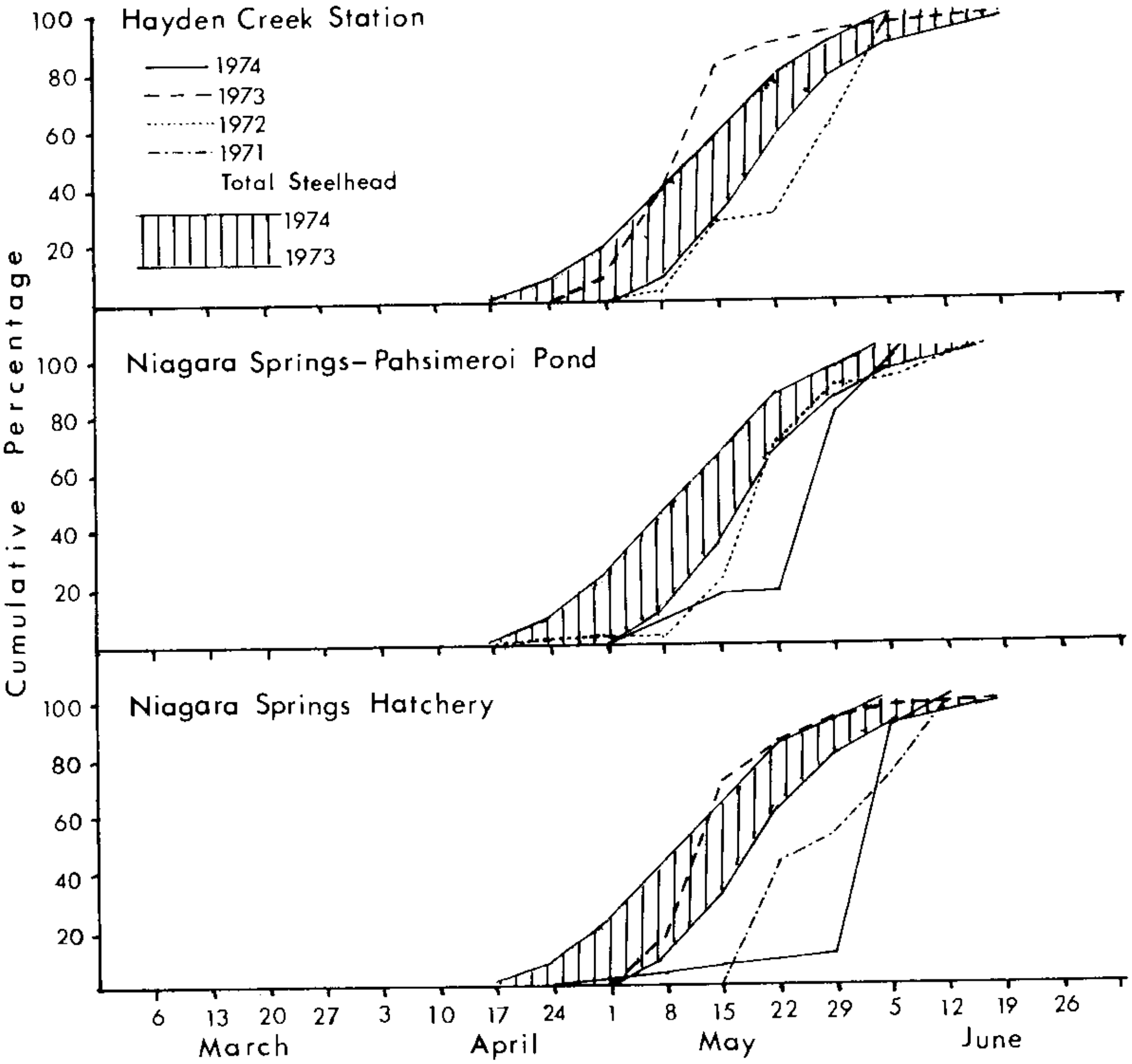

Figure 20. Cumulative catch curves of seaward migrating hatchery steelhead trout from Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery released at the hatchery site or in the Pahsimeroi River and recaptured at Ice Harbor Dam, 1971-74. The shaded area illustrates the difference in cumulative catch curves of all seaward migrating steelhead trout (wild and hatchery) collected at Ice Harbor Dam in 1973 versus 1974.

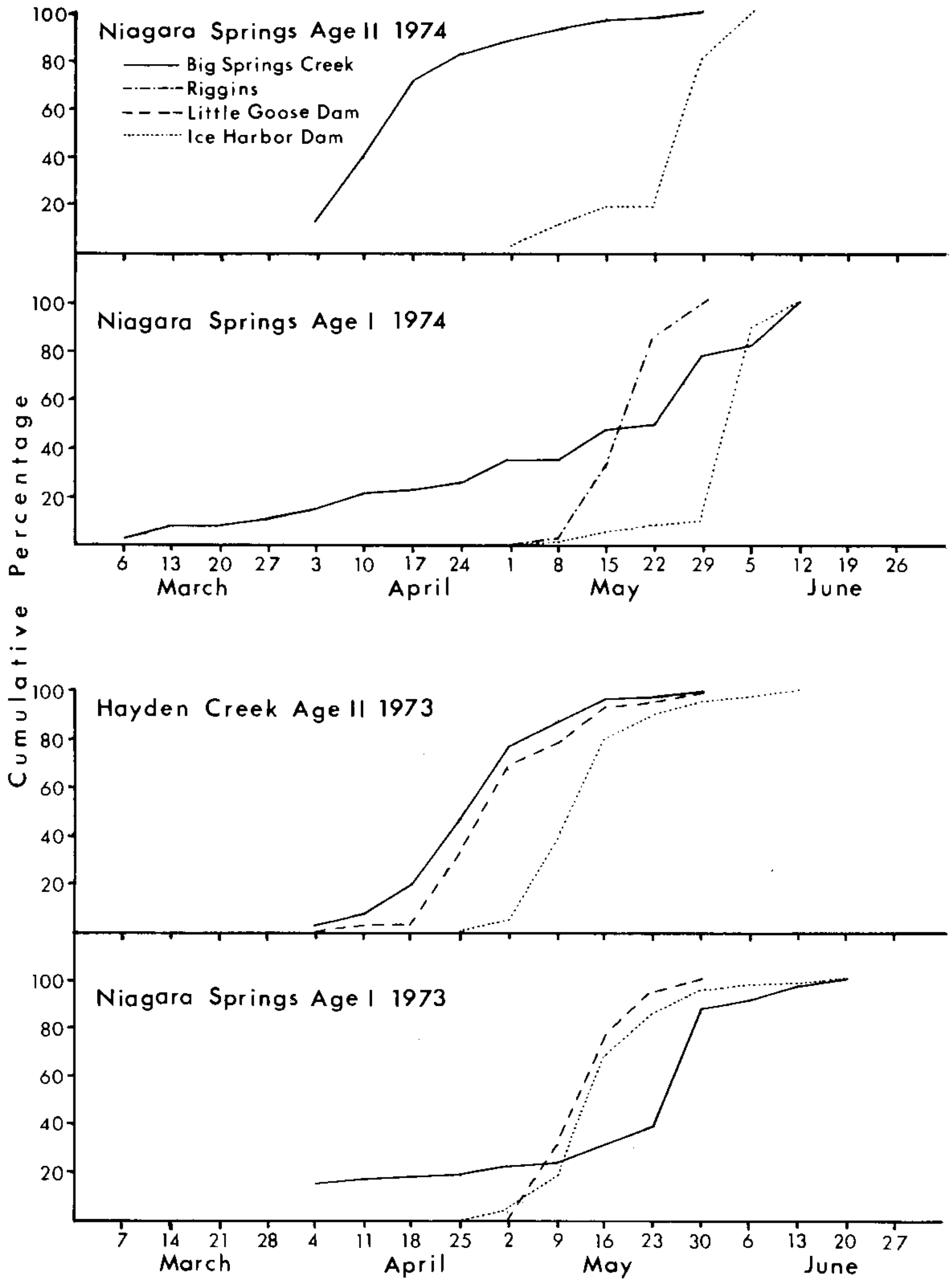

Figure 21. Cumulative catch curves of seaward migrating hatchery steelhead trout from Hayden Creek Station, Pahsimeroi pond, and Niagara Springs Hatchery released into Big Springs Creek, Hayden Creek or the Pahsimeroi River and recaptured at the Big Springs Creek weir, Riggins scoop trap, and at Little Goose (1973 only) and Ice Harbor dams, 1973 and 1974. Catch curves at the Riggins trap and the dams based on marked fish released in Hayden Creek or the Pahsimeroi River.

Table 17. Date of peak catch, median migration date, and duration of seaward migration of marked hatchery steelhead trout at Ice Harbor Dam, 1971-74.

Hatchery	Year	Peak Catch	Median migration date	Duration
Hayden Creek Station				
	1973	4/27	5/3	33
	1972	5/4	5/16	13
Niagara Springs - Pahsimeroi Pond				
	1974	6/4	6/4	22
	1972	5/14	5/16	13
Niagara Springs Hatchery				
	1974	6/3	6/5	7
	1973	5/15	5/16	19
	1971	5/27	6/3	17

Steelhead trout smolts from the Hayden Creek Station, Pahsimeroi pond, and the Niagara Spring Hatchery normally contribute only to the latter segment of the outmigration at Ice Harbor Dam (Fig. 20). Smolts which migrate late in the season may have less chance of reaching the ocean because of increased nitrogen supersaturation, temperatures, and abundance of predator fish. Raymond et al. (1974 and 1975) reported that more steelhead trout smolts discontinued their migration and held over in Snake and Columbia River reservoirs in 1973, a year of small spring flows, than in 1974, a year with high runoff during the spring.

Hatchery steelhead trout which do not migrate from release sites in the upper parts of the Columbia River drainage until late May or June probably do not reach the ocean in years of low runoff such as 1973 (Fig. 21). We believe many of the age I steelhead trout released from Niagara Springs hatchery in 1973 did not reach the ocean, if the timing of their migration from the Pahsimeroi River was similar to Niagara Springs Hatchery fish we released in Big Springs Creek (Fig. 21). Niagara Springs age I fish were still migrating out of Big Springs Creek after fish had stopped migrating past Ice Harbor Dam in 1973 (Fig. 21). Hayden Creek age II fish in 1973 and Niagara - Pahsimeroi age II fish in 1974 completed their migration from Big Springs Creek ahead of the migration at Ice Harbor Dam.

Length of Migrants

Wild rainbow-steelhead trout collected at the Big Springs Creek weir during the spring migration period (March through June) composed two distinct length (age I and II) groups (Fig. 22). Wild rainbow-steelhead trout collected at the Lemhi River weir and at recovery sites in the Snake and Columbia rivers during the same time period composed one length group (Figs. 22 and 23). Ebel et al. (1973b), examined scales of wild adult Snake River steelhead trout and found that all adults had lived two years or more in freshwater before migrating to the sea.

Age II wild steelhead trout smolts collected at our weirs ranged from 140 to 240 mm in length (Fig. 22). Ignoring fish shorter than 150 mm, wild migrants collected from the Big Springs Creek trap averaged 191 $\pm$ 22 mm (mean $\pm$ standard deviation, n = 492) in 1973 and 193 $\pm$ 19 mm (n = 1629) in 1974. Wild migrants (longer than 150 mm) out of the upper Lemhi River averaged 188 $\pm$ 26 mm (n = 172) in 1973 and 196 $\pm$ 20 mm (n = 1170) in 1974. Wild fish collected at Riggins (Salmon River) in 1974 averaged 180 mm (n = 163), 191 mm (n = 225) at Little Goose Dam, 189 mm (n = 1596) at Ice Harbor Dam (Snake River), and 189 mm (n = 75) at The Dalles Dam (Columbia River) (Fig. 23).

Hatchery steelhead trout recaptured at the Big Springs Creek weir, Riggins scoop trap, and at Little Goose, Ice Harbor, and The Dalles dams were similar in length to wild fish. Fish from the Hayden Creek Station (1973), Pahsimeroi pond (1974), and Niagara Springs Hatchery (1973 and 1974) ranged from 140 to 340 mm in length when collected at the weirs and dams (Fig. 24). Fish collected at the downstream sites were longer than fish collected at the upper sites (Fig. 24 and Table 4). The longer length may be the result of growth during migration and the failure of smaller fish to reach the lower recovery sites.

For most groups, hatchery steelhead trout which migrated downstream out of Big Springs Creek did not differ significantly in length at release regardless of the month they migrated (Table 18). The migrants, however, were often longer at time of migration than when released in the creek (Table 18 and Fig. 24).

Marked hatchery steelhead trout collected at Ice Harbor Dam in 1973 and 1974 varied in length as the migration season progressed (Table 19). Fish from the Pahsimeroi pond and Niagara Springs Hatchery collected in May 1974 were larger than fish collected in June. Steelhead trout from Hayden Creek Station and Niagara Springs Hatchery collected in May 1973 were smaller than those collected in June.

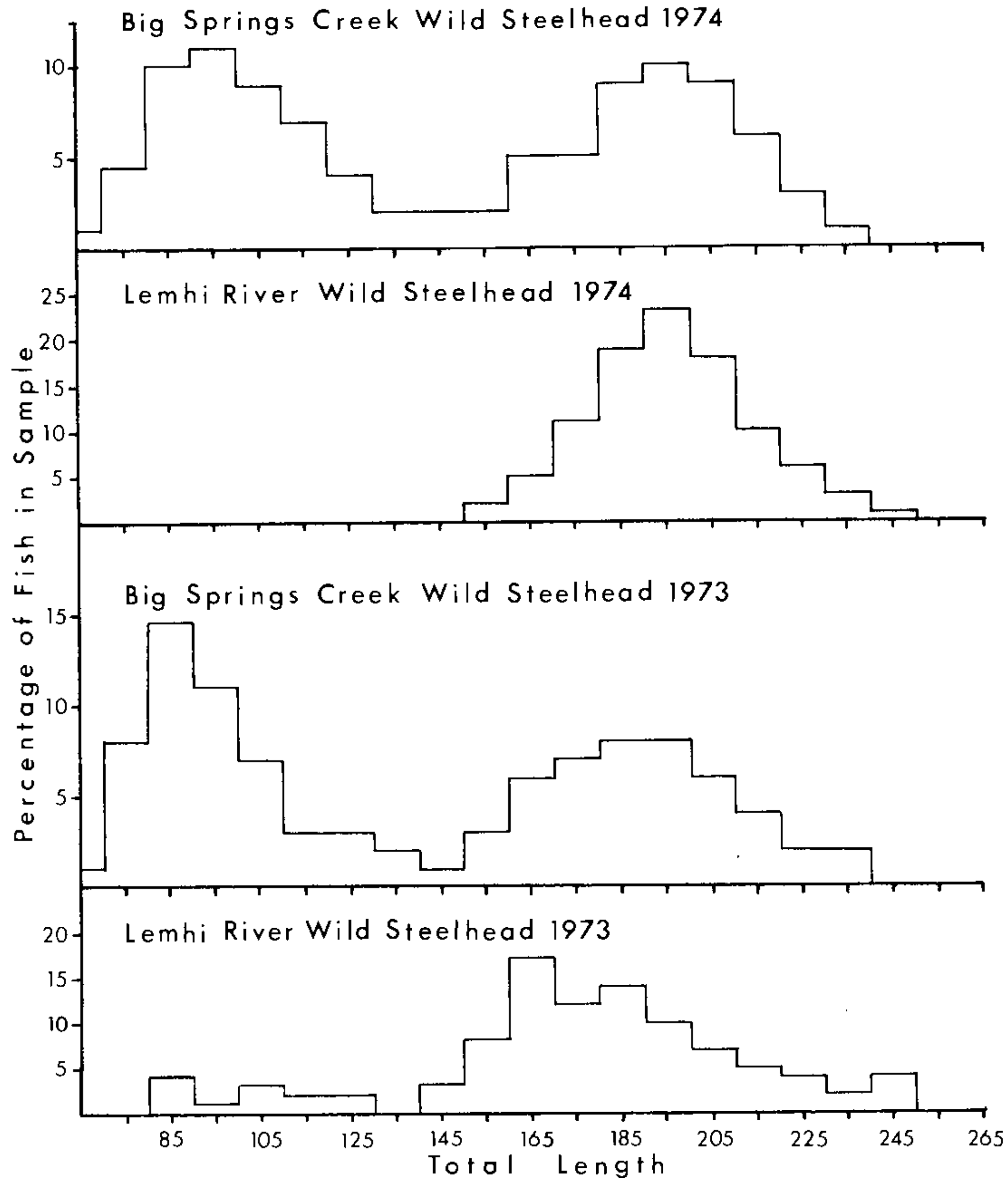

Figure 22. Length-frequency of seaward migrating wild steelhead trout collected during the spring migration period (March through June) at the Big Springs Creek and Lemhi River weirs, 1973 and 1974.

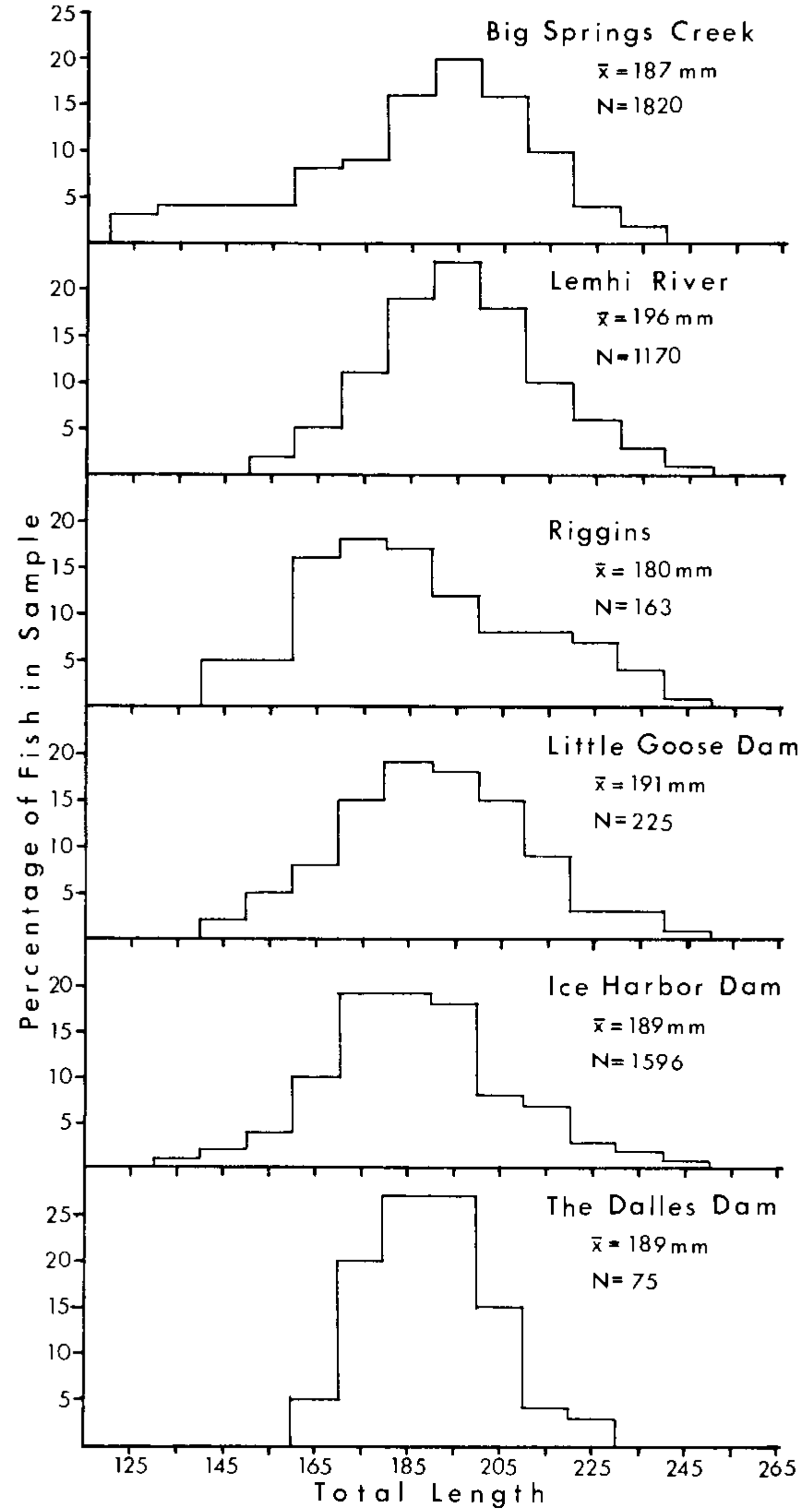

Figure 23. Length-frequency of seaward migrating wild steelhead trout collected at the Big Springs Creek and Lemhi River weirs, Riggins scoop trap, and Little Goose, Ice Harbor, and The Dalles dams, 1974.

Table 18. Mean lengths of seaward migrating hatchery steelhead trout at release and at recovery, from Big Springs Creek, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Length of fish for each month at release and recovery													
	March release					April release				May release			June release	
Release group	March	April	May	June	F	April	May	June	F	May	June	F	June	F
Hayden Creek age II 1974														
Migrants at release	178	182	183	187	0.74	193	185	169	6.20**					
Migrants at recovery	178	186	200	215	13.80**[a]	195	198	198	0.92					
Hayden Creek age I 1974														
Migrants at release	169	172	172	171	0.84	175	179	167	1.28	184	181	0.57	189	----
Migrants at recovery	167	174	185	178	25.33**	175	187	184	17.26**	187	194	2.42	190	----
Niagara-Pahsimeroi age II 1974														
Migrants at release						216	209	218	2.76					
Migrants at recovery						216	218	233	0.19					
Niagara Springs Age I 1974														
Migrants at release	170	177	167	172	2.01	168	171	168	0.35	179	178	0.18		
Migrants at recovery	169	180	184	198	6.74**	169	188	189	12.04**	181	191	6.95*		
Niagara Springs age I large 1974														
Migrants at release	170	177	167	172	2.01	188	186	182	0.80	207	203	1.75	209	----
Migrants at recovery	169	180	184	198	6.74**	189	195	200	5.62**	210	213	0.45	210	----
Hayden Creek age II 1973														
Migrants at release						215	211	----	1.03	205	174	7.46**	205	----
Migrants at recovery						219	222	----	1.04	209	209	0.66	206	----
Niagara Springs age I 1973														
Migrants at release						188	182	166	5.82**	185	178	12.74**	186	----
Migrants at recovery						188	204	195	20.05**	196	197	0.39	191	----

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

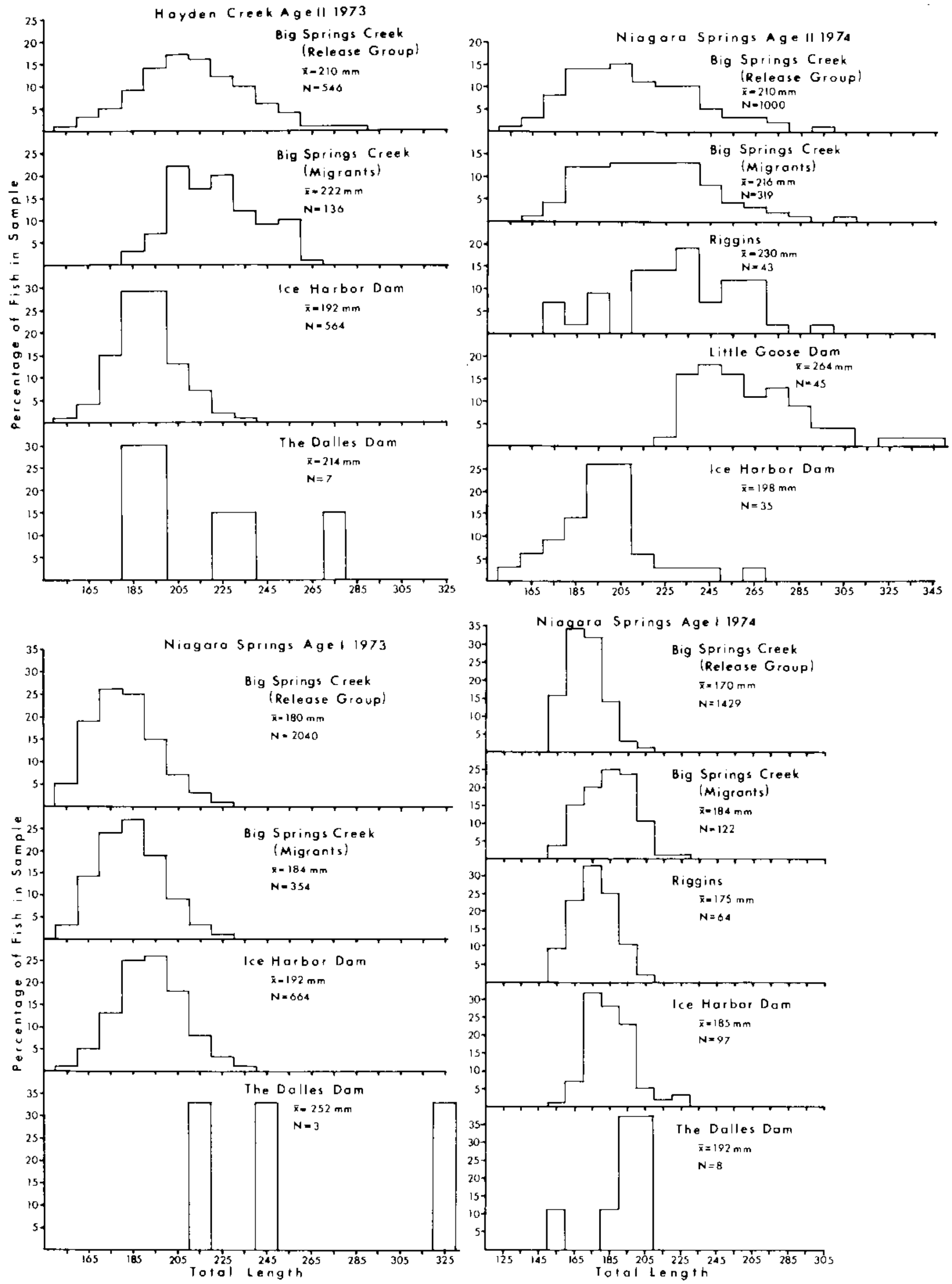

Figure 24. Length-frequency of hatchery steelhead trout released into Big Springs Creek, Hayden Creek, or the Pahsimeroi River and recaptured at the Big Springs Creek weir, Riggins scoop trap, and at Little Goose, Ice Harbor, and The Dalles dams, 1973 and 1974.

Table 19. Mean lengths of seaward migrating hatchery steelhead trout when recaptured at Ice Harbor Dam, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

Release Group	Month collected			F
	April	May	June	
Niagara - Phasimeroi Age II 1974		224	193	9.48**[a]
Niagara Springs Age I 1974	<u>162</u>	208	<u>182</u>	21.90**
Hayden Creek Age I 1973		191	201	11.33**
Niagara Springs Age I 1973		192	203	13.06**

[a]* = Significant at $P \leq 0.05$ and ** = Significant at $P \leq 0.01$.

FACTORS INFLUENCING PARR-SMOLT TRANSFORMATION OF HATCHERY FISH

Juvenile summer steelhead trout released from Idaho hatcheries will migrate seaward if they have completed the parr-smolt transformation. We evaluated the effect of time of release, length at release, age at release, rearing in warm water versus cold water and cold water conditioning on parr-smolt transformation (as measured primarily by migratory behavior) of hatchery steelhead trout. Ideally, the release stream serves only as a highway to the sea and not as a post-liberation rearing area for hatchery fish (Wagner 1968). Hatchery fish which do not migrate seaward soon after release may compete for food or space with wild fish.

Time of Release

Many experiments have been conducted to determine the optimum date to release hatchery-reared winter steelhead trout (Pautzke and Meigs 1940; Larson and Ward 1954; Hallock et al. 1961; Wagner et al. 1963; Wagner 1968) but few studies on summer steelhead trout (Fessler 1971, 1972, and 1973; Reingold 1974 and 1975b). Hatchery fish survived best when released during the normal wild fish migration period (March to May). Wagner (1968) found that allowing the fish to leave the hatchery voluntarily did not increase survival significantly.

We released groups of marked steelhead trout from the Hayden Creek Station and Niagara Springs Hatchery into Big Springs Creek near the first of March, April, May, and June. The March release date was selected to evaluate the migration of fish released 4-6 weeks prior to the peak period of downstream migration by wild fish. Fish were released in June to determine what proportion of the fish released after the peak of migration would try to migrate, even though they might not reach the ocean.

Hayden Creek Age II Fish

We released marked Hayden Creek age II steelhead trout into Big Springs Creek on March 2 and March 30, 1974. The fish averaged 180 ± 16 mm (n = 500) and 184 ± 18 mm in length (n = 500), respectively. We recaptured 15% of the fish released in March and 33% of those released in April at the Big Springs Creek weir (Table 15). The median migration dates were April 21 and April 29, respectively. The March 2 released fish migrated approximately a week earlier than fish released March 30 (Fig. 25), and both groups completed migration before June 1.

In 1973, we marked and released age II steelhead trout from the Hayden Creek Station on April 1, April 28, and June 3 and the fish averaged 210 ± 28 mm (n = 546), 203 ± 24 mm (n = 752), and 205 ± 27 mm (n = 661) in length, respectively. Twenty-five percent of the fish released in early April, 12% of the April 28 release, and 6% of the June 3 release were recovered at the Big Springs Creek weir (Table 15).

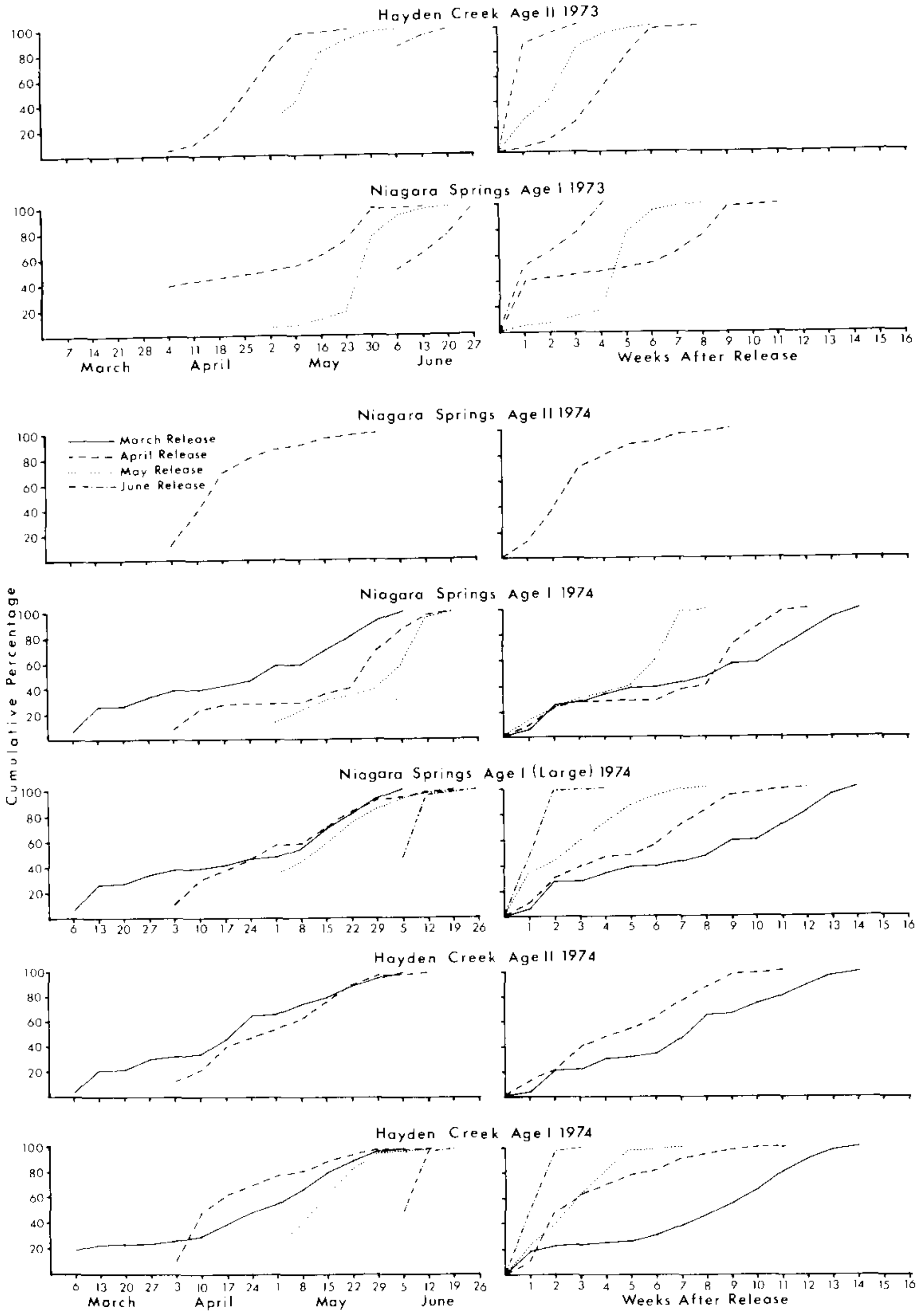

Figure 25. Cumulative catch curves of seaward migrating hatchery steelhead trout released at about the first of each month into Big Springs Creek and recaptured at the weir, 1973-74.

Age II steelhead trout released in 1973 migrated primarily during the first month after release; 63% of the April 1 release and 95% of the April 28 release that were recaptured (Fig. 25). Fish released April 1, 1973 migrated earlier than fish released April 28 (Fig. 25). The median migration date of the fish released April 1 was 15 days earlier than the April 28 release group.

Only 6% of the Hayden Creek age II steelhead trout released the first of June in 1973 were recaptured while migrating from Big Springs Creek. Most of the fish had apparently reverted back to the parr stage. The steelhead that did migrate, did so immediately after release (Fig. 25). The median migration days was 1 day and duration of migration was only 7 days (Table 15). The last migrants from the June release group were recaptured on June 18.

A significant number of the hatchery age II steelhead trout remained in Big Springs Creek after the migration season in both 1973 and 1974. In July 1973, we recaptured 5 fish from the April 1 release, 14 from the April 28 release, and 19 fish from the June 3 release. An estimated 10 ± 3% (estimated percentage of release groups remaining in Big Springs Creek ± 95% confidence interval) of the fish released April 1, 21 ± 6% of the April 28 fish, and 33 ± 8% of the fish released June 3 were present in Big Springs Creek in July 1973 (Table 16). Based on the recapture of 2 steelhead trout from the March 2 release and 7 from the March 30 release, an estimated 3 ± 0% and 12 ± 1%, respectively, of the two groups released in 1974 were present in Big Springs Creek in July (Table 16). The large percentage of Hayden Creek age II steelhead released in May and June 1973 which did not migrate indicates that many of those fish did not go through parr-smolt transformation, were in the process of reverting to parr when released (especially the fish released June 3), or the handling and transportation to Big Springs Creek had upset the fish sufficiently to prevent migration.

On the basis of Hayden Creek age II steelhead trout released in Big Springs Creek in 1973 and 1974 and recovered at the weir, early to mid-April appears to be the optimum time of release. The larger two year old fish started the parr-smolt transformation and began migrating earlier than smaller fish reared for only 1 year.

Hayden Creek Age I Fish

On March 2, March 31, April 28, and June 1, 1974 (referred to as March, April, May and June releases), we released 500 age I steelhead trout from the Hayden Creek Station into Big Springs Creek (Table 15). The mean length of the fish ranged from 169 ± 9 mm in March to 184 ± 13 mm in June.

The May release of fish had the largest number of downstream migrants of any hatchery group released (Table 12). Sixteen percent of the fish in the March release, 17% of the April, 43% of the May, and 24% of the June groups were recovered at the Big Springs Creek weir. The percentage of the May release group fish recovered the first 15 days after release, was larger than the total recovery of fish released in March or April (Table 15).

Active migration of the fish released March 2 began the second week in April and continued through the fourth week of May (Fig. 25). Steelhead trout released March 2 did not migrate earlier than fish released March 31. The median migration date of the March 2 fish was 15 days later than that of the March 31 fish (Table 15). Median migration dates for the March, April, and May release groups were April 29, April 14, and May 14, respectively. The median migration days for steelhead from the April release group was 14 compared to 16 for fish from the May release group, and 58 days for fish released in early March (Table 15). Virtually all of the Hayden Creek age I fish that were going to migrate had done so by the first of June; 97% of the March 2 release, 99% of the March 31 release, and 95% of the migrants from the April 28 release had passed the Big Springs Creek weir site.

Many of the Hayden Creek age I steelhead trout released the first of June were ready to migrate and did so immediately after release. The median migration days was 7 and duration of migration was only 9 days (Table 15). The last migrant was recaptured at the Big Springs Creek weir trap on June 17.

A significant number of the age I Hayden Creek steelhead trout remained in Big Springs Creek after the migration season. We recovered 25 fish released April 28 and 19 released June 1 when we electrofished sections of the creek in July 1974. An estimated 41 ± 3% of the May release and 49 ± 3% of the fish released in June were present in Big Springs Creek in July. None of the fish released March 2 or March 31, 1974 were recovered in July (Table 16).

Late April appears to be the optimum time of release for age I fish based on the recovery of Hayden Creek age I steelhead trout released in Big Springs Creek in 1974. The additional growth in the hatchery during early April appears to be important to successful completion of the parr-smolt transformation process.

Niagara - Pahsimeroi Age II Fish

We released only one group of age II steelhead trout from Niagara Springs Hatchery and the Pahsimeroi pond into Big Springs Creek on March 30, 1974. Fish of this group migrated from Big Springs Creek early in the season (median migration date, April 18) and a relatively large percentage were recaptured (32%) at the Big Springs Creek weir (Table 15).

In 1974, Idaho Department of Fish and Game personnel monitored the migration of the Niagara - Pahsimeroi age II steelhead trout from the Pahsimeroi River. Reingold (1975b) reported collecting the age II steelhead trout from the last week of March to the end of May, with 50% of the marked fish collected at the Burstedt Lane migrant trap (lower end of Pahsimeroi River) during the week of April 16-23. The Niagara -

Pahsimeroi age II fish released into Big Springs Creek and those released into the Pahsimeroi River migrated primarily during April. The optimum release date for age II steelhead trout from the Pahsimeroi pond appears to be similar to that of age II fish from the Hayden Creek Station--early April.

Niagara Springs Age I Fish

We released three groups of age I fish from Niagara Springs Hatchery that were representative of the normal production fish into Big Springs Creek on March 2, March 30, and April 27, 1974 (Table 15). The fish released on each date were the largest fish still on hand at the hatchery and were similar in size to fish being released in the Pahsimeroi River at that time. The larger fish at Niagara Springs Hatchery were continually graded off for release into the Pahsimeroi River during the spring, thus there was little difference in mean length between the three groups (168-173 mm).

Few of the Niagara Springs age I fish released in Big Springs Creek were recovered at the Big Springs Creek weir (Table 15). Only 7% of the fish from the March 2 release, 10% of the March 30 release, and 12% of the April 27 release were recaptured.

A significant number of the Niagara Springs age I steelhead trout migrated late in the season which lessened their chance of reaching the ocean. Only the fish from the March 2 release completed migration by the first of June. Of the total migrants from the March 2 release, 91% were recaptured at the Big Springs Creek weir by June 1, compared to 71% of the March 30 release and 38% of the April 27 release. The last migrants from the March 30 and April 27 release groups were recaptured at the Big Springs Creek weir on June 18 and 19.

We did not recover a large number of the Niagara Springs age I fish in Big Springs Creek in July 1974. An estimated 5 $\pm$ 0% of the fish from the March 30 release and 14 $\pm$ 1% of those released April 27 were present in July (Table 16).

In 1973, we released three groups of marked age I steelhead trout from Niagara Springs Hatchery into Big Springs Creek (Table 15). These fish were moved from Niagara Springs Hatchery to the Hayden Creek Station in February 1973, and released on March 31, April 28, and June 2. There was little difference in mean length between the three groups when released (178-183 mm).

A larger percentage of the Niagara Springs age I steelhead trout released in 1973 were recaptured at the Big Springs Creek weir than of those released in 1974; 13% of the fish from the March 31 release, 22% of the April 28 group, and 15% of the June 2 release (Table 15).

The Niagara Springs age I fish released in 1973 spent less time in Big Springs Creek before migrating than the fish released in 1974 (Table 15). In 1973, the median migration days for fish released March 31 was 37, compared to 33 for fish released April 28, and 5 days for fish released in June. In 1974, the median migration days for fish released March 30 and April 27 were 58 and 39, respectively.

There was an initial delay in migration of 3-5 weeks after release for fish in both the March 31 and April 28 release groups in 1973 (Fig. 25). We recaptured only 6% of the fish in the March 31 release and 1% of the April 28 release during the first 15 days after release (Table 15). By the first of June, 92% of the migrants from the March 31 release group had passed the weir site, and 62% of the Migrants from the April 28 release. The larger proportion of migrant and earlier migration of Niagara Springs age I fish in 1973 versus 1974 might have resulted from being held 6-15 weeks in colder water at the Hayden Creek Station before release.

In July 1973, we recaptured 12 steelhead trout from the March 31 release, 18 from the April 28 release, and 20 from the June 2 release (Table 16). An estimated 13 ± 3% of the March 31 release, 20 ± 5% of the April 28 release, and 31 ± 8% of the fish released June 2 were present in Big Springs Creek in July.

Niagara Springs Age I Large Fish

In 1974, we marked and released into Big Springs Creek four groups of the larger, faster growing steelhead trout at Niagara Springs Hatchery (Table 15). Fish for the four groups were set aside during February and held at the hatchery until release on March 2, March 20, April 27, and June 1. The fish released March 2 were the same as the regular March release from Niagara Springs Hatchery because they were the largest fish at the hatchery on the first of March. The fish in the March 2 release averaged 169 ± 8 mm (n = 500) in length. The fish released after March 2 were larger because of the additional time in the hatchery and averaged 183 ± 11 mm (n = 500) in length for the March 20 release, 203 ± 14 mm (n = 491) for the April 27 release, and 218 ± 13 mm (n = 495) for the June 1 release.

Nearly equal proportions of the fish from the March 20, April 27 and June 1 releases were recaptured at the Big Springs Creek weir (Table 15). Only 7% of the fish released in early March were recaptured compared to 18% of the April release, 21% of the May release, and 21% of the June release.

About half of the Niagara Springs age I, large fish released before May 1, migrated from Big Springs Creek during May (Fig. 25). The median migration date for the March 2, March 20 and April 27 releases were May 1, May 10, and May 13, respectively (Table 15). The median migration dates for the three groups were within 13 days of each other even though the fish were released as much as 56 days apart. The duration of migration and mean number of days out decreased with each succeeding release date.

The median migration days were 60 for the March 2 release, 41 for the March 20 release and 16 for the April 27 release (Table 15). The group released the first of June had as many migrants as earlier release groups, and the fish migrated soon after release (median migration days was 8 and duration of migration was 10 days) but their chances of reaching the ocean would normally be low because of the lateness of the migration.

In our July 1974 electrofishing in Big Springs Creek, we recovered 1 Niagara Springs large steelhead trout from the March 20 release, 13 from the April 27 release, and 34 from the June 1 release (Table 16). Estimates of the percentage of Niagara Springs large steelhead remaining in Big Springs Creek in July were 2 ± 0% of the fish released March 20, 23 ± 2% of the April 27 release and 60 ± 4% of the June 1 release. The large percentages of residual steelhead trout from the April 27 and June 1 releases are an indication that many of the Niagara Springs Hatchery steelhead released late in the migration season had lost whatever urge to migrate they had.

Based on the recaptures at the weir of Niagara Springs age I and age I large steelhead trout released in Big Springs Creek in 1973 and 1974, late April appears to be the optimum date for release of age I Niagara Springs fish. Additional rearing of the large fish at the hatchery during March and April increased the number of migrants and improved the timing of migration.

Idaho Department of Fish and Game personnel marked and released three groups (20,000 fish each) of Niagara Springs age I steelhead trout into the Pahsimeroi River in 1974. They released the first group on March 11, the second April 1-3, and the last May 1-5 into the Pahsimeroi River adjacent to the Pahsimeroi acclimation pond (Reingold 1975b). Department personnel monitored the migration of the marked steelhead trout from the Pahsimeroi River at the Burstedt Lane downstream migrant trap (17.7 km, downstream from the release site). Reingold (1975b) reported that 60% of the recaptured fish from the March 11 release were taken within 3 weeks of release. Migration virtually stopped for 3 weeks and the remaining 40% of the recaptured fish were taken during late April and May. Forty-eight percent of the recaptured fish from the April 1-3 release were taken immediately after release, and the remainder during late April and May. Migrants from the May release were recaptured during the first two weeks after release. Reingold collected fewer of the fish released in May (11) than from those released in March (28) or April (29). The trap was operated through May 24, 1974.

At the Riggins scoop trap, National Marine Fisheries Service personnel recaptured 33 marked Niagara Springs fish released in the Pahsimeroi River March 2, 20 from the April release, and 11 from the May release. At Ice Harbor Dam, they recaptured 9, 28, and 60 marked fish from the March, April, and May releases, respectively. The differences in numbers of fish from the three release groups recaptured at Riggins and Ice Harbor Dam probably resulted from seasonal changes in collection efficiency and earlier termination of trapping (May 26) at Riggins. The collection efficiency at the Riggins scoop trap decreased as flows increased during May, thus the number of migrants collected from the May release probably does not reflect their true abundance. If most of the fish from the May release group delayed 3-5 weeks before migrating from the Pahsimeroi River, as the May release into Big Springs Creek did, then the peak of migration at the Riggins site would have occurred after the Riggins scoop trap had been shut down. The number of fish recovered at Ice Harbor Dam is probably a more accurate measure of the abundance of the three groups of fish passing down the Snake River.

Although many of the fish released in March and early April apparently left the Pahsimeroi River soon after release, the migrants from all three release groups passed the Riggins and Ice Harbor recovery sites at the same time (late May and early June; Fig. 26). Although the timing of migration at the Riggins scoop trap appears to be the same for all three release groups (Fig. 26), the discontinuance of trap operation on May 26 probably prevented us from obtaining the true timing.

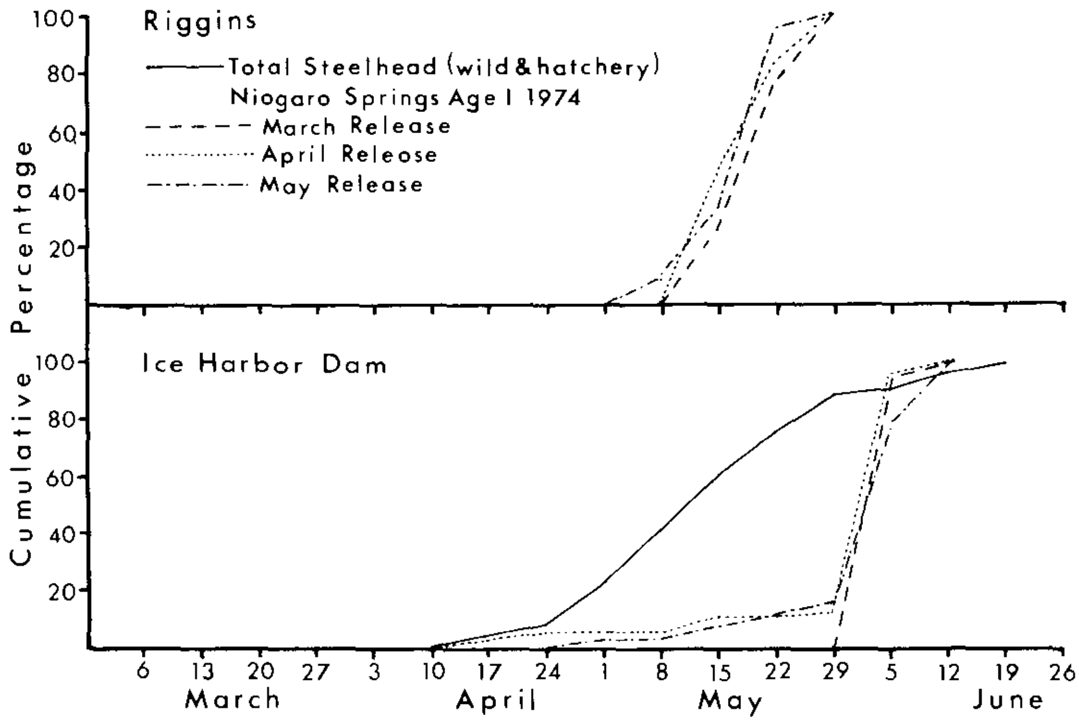

Figure 26. Cumulative catch curves of seaward migrating Niagara Springs age I steelhead trout marked and released (March, April, and May) into the Pahsimeroi River and recaptured at the Riggins scoop trap and Ice Harbor Dam, 1974.

A clearer picture of the effect of release time will be obtained when adults return to the Pahsimeroi River in 1976 and 1977. If the fish released in May return in equal or larger numbers than the March or April released fish, the late April or early May date would appear best for the release of age I hatchery fish. The age I Niagara Springs steelhead trout released in May of 1974 were probably the least likely to become migrating smolts. When released in May, they were no larger than the fish released 5 or 9 weeks earlier, and thus were from the late eggs or were the slowest growing fish at Niagara Springs Hatchery.

Another factor to consider in survival of fish released in May is the timing and volume of the spring runoff. In 1974, the runoff was large and extended well into June so that the late migrating fish had an improved chance of reaching the ocean. In some years, such as 1973, with small early runoffs, fish released in May would have less chance of migrating successfully to the ocean than fish released earlier.

Length at Release

Parr-smolt transformation in steelhead trout is size dependent. Wild steelhead trout must reach a critical length (140-180 mm fork length) before they will become smolts and migrate to the sea (Wagner et al. 1963). Wild steelhead trout spend one to four years in streams before seaward migration (Chapman 1958), but the goal of most hatchery programs is to to produce smolts of proper size in one year. Hatchery steelhead trout produced in a one-year rearing program must be as long if not longer than wild smolts. Wagner et al. (1963) indicated that if hatchery fish did not reach the critical length they would not go through the parr-smolt transformation process and would residualize in the release streams. Other investigators have shown that increased adult returns can be expected with increased size of smolts at release (Wagner et al. 1963, Hallock et al. 1961, Larson and Ward 1954, Wallis 1968, Royal 1972, and Everest 1973).

In this section we discuss the effect of size on parameters we used to assess parr-smolt transformation and evaluate the differences in the migration of hatchery steelhead trout. We compared the length at release with rate of recovery at the Big Springs Creek weir and the timing of migration. We divided the test groups into either 10 mm length classes or into three size groups depending on the analysis. Fish in the smallest size group were 150 to 169 mm total length, the medium-size fish ranged from 170 to 199 mm and the large-size fish were longer than 200 mm.

Wild steelhead trout migrants classified as smolts averaged 194 $\pm$ 18 mm in length (n = 176), intermediates 180 $\pm$ 13 mm (n = 33), and parrs 178 $\pm$ 9 mm (n = 11) and the means were significantly different ($F = 19.72$; df = 2,218; $P \leq 0.01$). Hatchery steelhead trout classified as smolts were significantly longer than intermediates, and intermediates were significant longer than parrs in almost all cases (Table 20 and Fig. 27).

Table 20. Mean lengths for appearance groups (smolt, intermediate, and parr) of hatchery steelhead trout recaptured at the Big Springs Creek weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Total length (mm) of fish when released															
	March release				April release				May release				June release			
Release group	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F
Hayden Creek age II 1974	---	203	180	5.39*[a]	248	188	178	49.61**								
Hayden Creek age II 1973	231	209	186	40.30**	227	206	192	53.58**	220	200	188	125.64**				
Hayden Creek age I 1974	174	169	161	69.39**	181	172	164	31.94**	193	178	162	67.53**	194	189	178	37.46**
Niagara-Pahsimeroi age II 1974	235	191	182	52.54**	222	197	186	128.13**	244	222	---	5.31*				
Niagara Springs age I 1974	183	172	165	95.85**	179	169	163	54.20**	188	174	163	101.92**				
Niagara Springs **large** age I 1974	183	172	165	95.85**	192	183	175	83.93**	211	199	182	81.53**	214	213	204	33.95**
Niagara Springs age I 1973	---	192	174	9.84**	---	191	177	90.71**	197	180	174	125.32**	189	182	176	19.59**

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

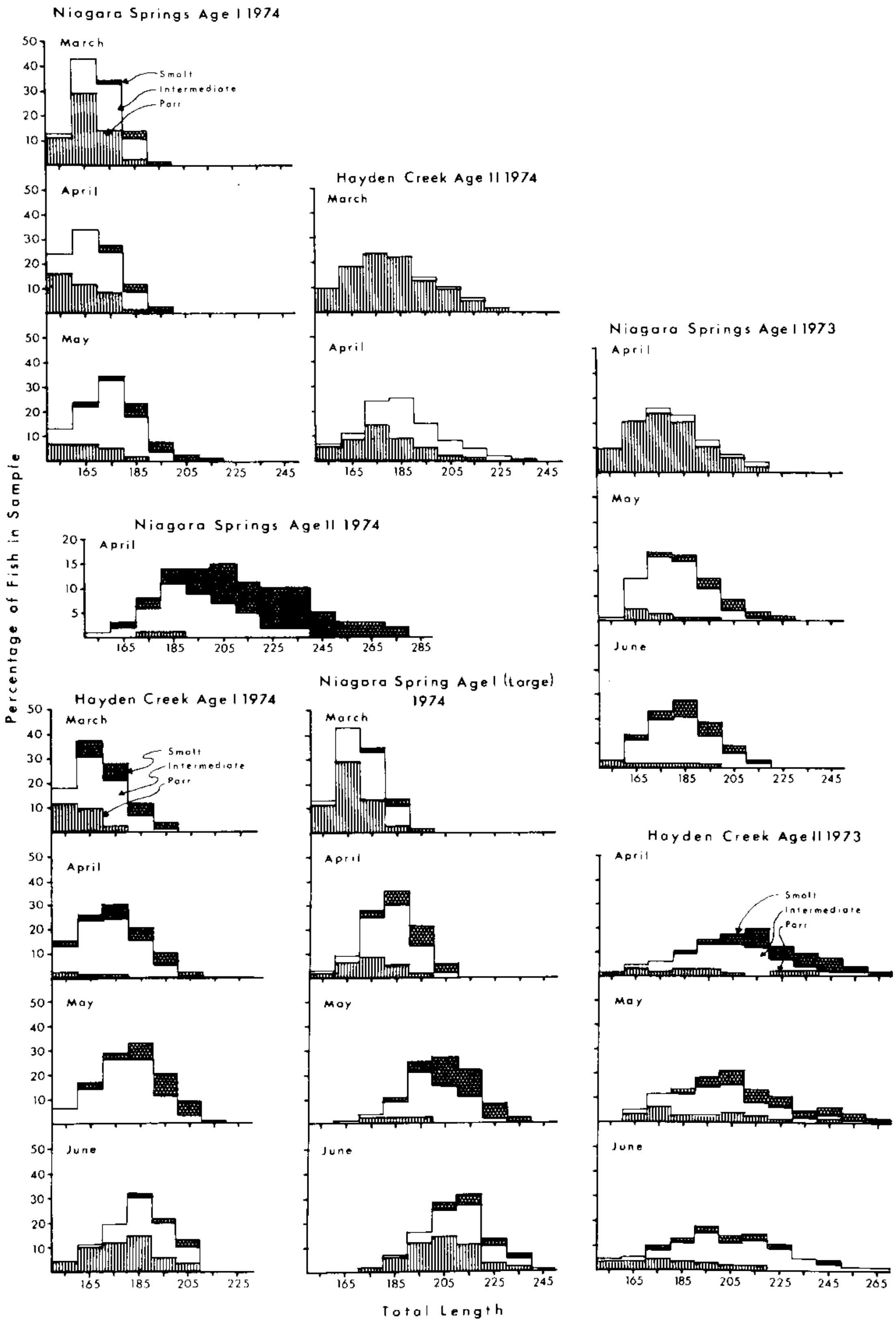

Figure 27. Length-frequency of hatchery steelhead trout classified as parr, intermediate, and smolts at time of release.

The percentage of fish in the three appearance groups changed seasonally and large fish developed the smolt appearance earlier than small fish (Fig. 28). Smaller steelhead trout classified as intermediates and parr early in the migration season were often classified later as smolts or intermediates which caused the mean lengths of those groups to decrease in some cases as the season progressed (Table 21).

The mean coefficient of condition of hatchery steelhead trout did not vary significantly, in most cases, between the three length groups (150 - 169 mm, 170 - 199 mm, and larger than 200 mm) (Table 22) or during the migration season (Table 23). Fessler and Wagner (1969) observed that migrant-sized (longer than 160 mm fork length) winter fish had a decrease in the coefficient of condition during the migration period, whereas, non-migrants (shorter than 160 mm) did not.

Hatchery steelhead trout that migrated from Big Springs Creek were generally larger (at release) than the release group as a whole or the non-migrants (Fig. 29 and Table 24). Hatchery fish which migrated from Big Springs Creek also grew while in the streams so that migrants recaptured at the weir were significantly longer than when they were released (Fig. 30 and Table 25).

The importance of length at release in the seaward migration of hatchery steelhead trout was apparent in the percentage recovered and timing of migration of each test group released in Big Springs Creek. Release groups composed of large fish (Hayden Creek age II 1973, Niagara - Pahsimeroi age II 1974, and Niagara Springs age I large 1974), generally, had a higher percentage of migrants (Table 12) and they migrated earlier (Fig. 16 and 17) than release groups composed of smaller fish.

When we divided the fish in each release group into 3 length groups (150-169 mm, 170-199 mm, and longer than 200 mm) we found that a higher percentage of the large steelhead trout were recaptured at the Big Springs weir than the smaller fish. On average, 3.5 times more steelhead trout from the 170-199 mm length group, and 4.9 times more steelhead from the 200 mm and longer group left Big Springs Creek from the April and May release groups than from the 150-169 mm length group (Table 26).

Using the percentage of fish migrating from each 10 mm length class, the relation between length of steelhead trout at release and percentage migration was linear (especially for fish less than 210 mm in length) (Fig. 31). On the basis of the slope of the regression lines of the April and May 1974 release groups, the number of migrants doubled with every 20 mm increase in length. There was some evidence of a decreased tendency to migrate for fish longer than 240-250 mm (Hayden Creek age II 1973 and Niagara - Pahsimeroi age II 1974; Fig. 31).

The slopes of the length-percentage recaptured regression lines were fairly consistent between most of the release groups, but the lines for steelhead trout from the Hayden Creek Station and the Pahsimeroi pond were usually higher than for fish from Niagara Springs Hatchery (Fig. 32).

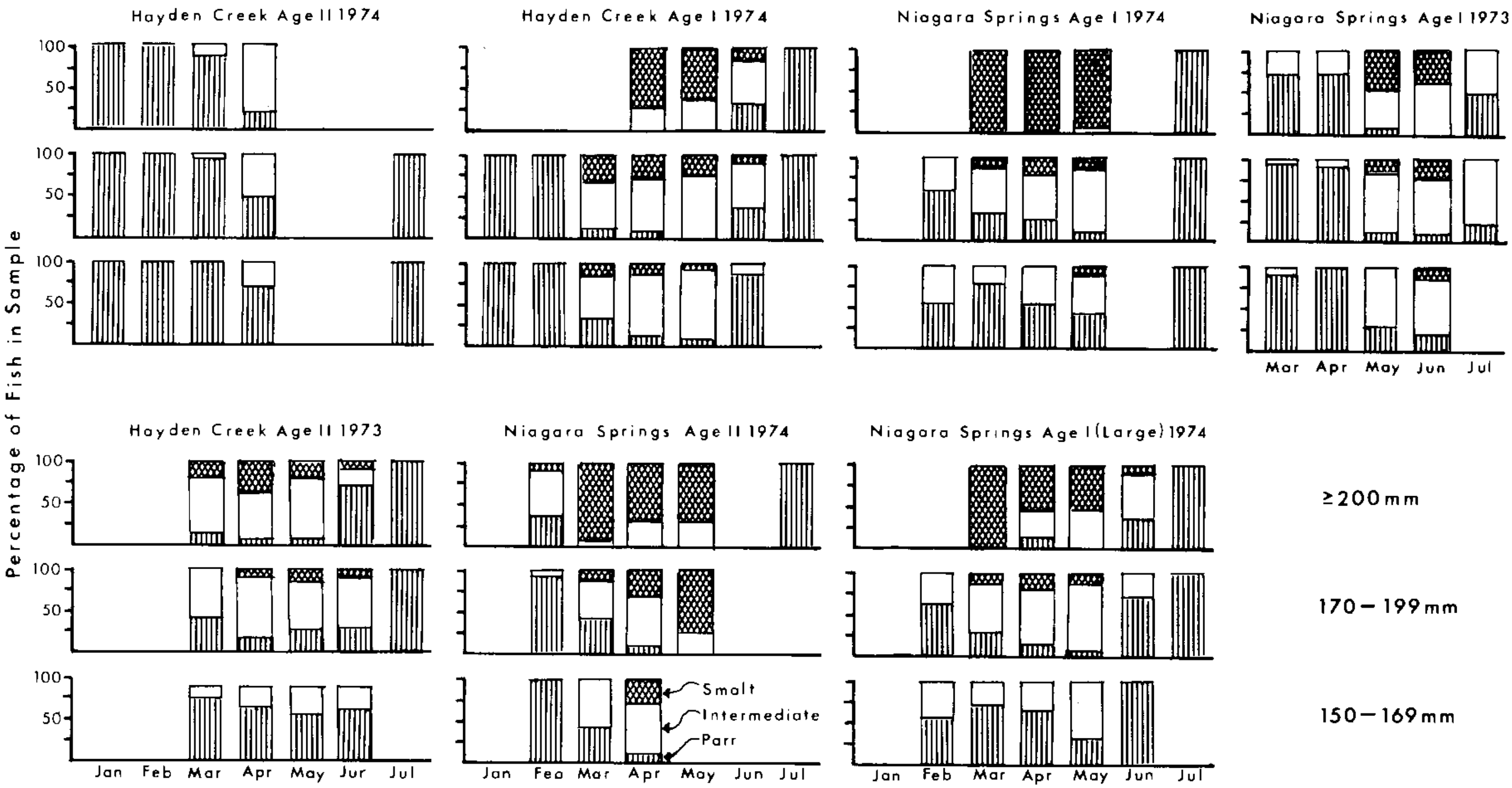

Figure 28. Percentage of fish classified as a smolt, intermediate, or parr by length group (150-169 mm, 170-199 mm, and longer than 200 mm) for hatchery steelhead trout during 1973 and 1974.

Table 21. Mean lengths of hatchery steelhead trout in the smolt, intermediate, and parr appearance groups before and after release into Big Springs Creek, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Total length (mm)																							
	Smolt								Intermediate								Parr							
Release group	Jan	Feb	Mar	Apr	May	June	July	F	Jan	Feb	Mar	Apr	May	June	July	F	Jan	Feb	Mar	Apr	May	June	July	F
Hayden Creek age II 1974				248				----			203	188				13.01**	174	173	180	178			223	10.90**
Hayden Creek age II 1973			231	227	220	213		9.19^{**a}			209	206	200	210		15.50**			186	192	185	181	205	13.27**
Hayden Creek age I 1974			174	181	193	194		54.96**			169	172	178	189		130.04**	144	154	161	164	162	178	202	127.52**
Niagara-Pahsimeroi age II 1974		276	235	222	244			11.48**		223	191	197	178	189		15.92**		192	182	186			237	10.94**
Niagara Springs age I 1974			183	179	188			6.88**		171	172	169	174			9.96**		172	165	163	163		206	42.11**
Niagara Springs age I large 1974			183	192	211	214		114.04**		171	172	183	199	213		50.89**		172	165	175	182	204	218	41.90**
Niagara Springs age I 1973					197	189	204	14.70**			192	191	180	182	200	19.98**			174	177	174	176	204	38.41**

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 22. Mean coefficient of condition of three length groups (150-169 mm, 170-199 mm, and ≥ 200 mm) of hatchery steelhead trout when released into Big Springs Creek, 1973-74. Means underlined by the same continuous or discontinuous single line are not significantly different from each other ($P \leq 0.05$).

	Coefficient of condition for fish each release date and length group															
	March release				April release				May release				June release			
Release group	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F
Hayden Creek age II 1974	0.701	0.718	0.748	0.77	0.716	0.702	0.728	0.20								
Hayden Creek age II 1973	0.787	0.771	0.814	9.08^{**a}	0.830	0.856	0.780	13.32^{**}	0.741	0.730	0.776	5.49^{**}	0.773	0.807	0.780	0.94
Hayden Creek age I 1974	0.746	0.744	0.751	0.07	0.743	0.748	----	0.26	0.712	0.712	----	0.01	0.717	0.713	-----	0.02
Niagara-Pahsimeroi age II 1974	0.693	0.704	0.709	0.55	0.766	0.738	0.739	0.68	-----	0.775	0.756	0.51				
Niagara Springs age I 1974	0.848	0.867		2.03	0.858	0.862		0.03	0.840	0.842	----	0.01				
Niagara Springs age I large 1974	0.848	0.867		2.03	0.836	0.850	0.860	0.85	-----	0.793	0.826	5.04^{*}	-----	0.803	0.826	0.02
Niagara Springs age I 1973	0.785	0.821	0.935	32.25^{**}	0.808	0.823	0.828	1.00	0.833	0.883	0.939	9.33^{**}				

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 23. Mean coefficient of condition of length groups (150-169 mm, 170-199 mm, and ≥ 200 mm of hatchery steelhead trout before release, at release, and when recaptured at the Big Springs Creek weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

Coefficient of condition for fish of each length group at various times during the spring

Release group	150-169 mm Jan	Feb	Mar	Apr	May	June	July	F
Hayden Creek age I 1974	0.765	0.716	0.701	0.701				4.66^{*a}
Hayden Creek age II 1973			0.787	0.830	0.741	0.773		6.98
Hayden Creek age I 1974	0.793	0.740	0.744	0.743	0.712	0.717		9.64^{**}
Niagara-Pahsimeroi age II 1974		0.698	0.693	0.766				2.83
Niagara Springs age I 1974		0.846	0.848	0.858	0.840			0.28
Niagara Springs age I large 1974		0.846	0.848	0.836				0.11
Niagara Springs age I 1973			0.785	0.808	0.833	0.822		2.43

Release group	170-179 mm Jan	Feb	Mar	Apr	May	June	July	F
Hayden Creek age I 1974	0.815	0.723	0.718	0.702			0.940	21.58^{**}
Hayden Creek age II 1973			0.771	0.856	0.730	0.807	0.820	26.00^{**}
Hayden Creek age I 1974		0.751	0.751	0.748	0.712	0.713	0.764	8.52^{**}
Niagara-Pahsimeroi age II 1974		0.748	0.704	0.738	0.775			5.06^{*}
Niagara Springs age I 1974		0.866	0.867	0.862	0.842		0.837	1.02
Niagara Springs age I large 1974		0.866	0.867	0.850	0.793	0.803	0.740	8.92^{**}
Niagara Springs age I 1973			0.821	0.823	0.883	0.758	0.850	12.50^{**}

Release group	≥ 200 mm Jan	Feb	Mar	Apr	May	June	July	F
Hayden Creek age I 1974	0.759	0.802	0.748	0.728			0.864	1.44
Hayden Creek age II 1973			0.814	0.780	0.776	0.780	0.835	4.44^{**}
Hayden Creek age I 1974						0.857		----
Niagara-Pahsimeroi age II 1974		0.760	0.709	0.739	0.756		0.848	16.52^{**}
Niagara Springs age I 1974							0.865	----
Niagara Springs age I large 1974				0.860	0.826	0.826	0.783	5.50^{**}
Niagara Springs age I 1973			0.935	0.828	0.939	0.909	0.851	9.17^{**}

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

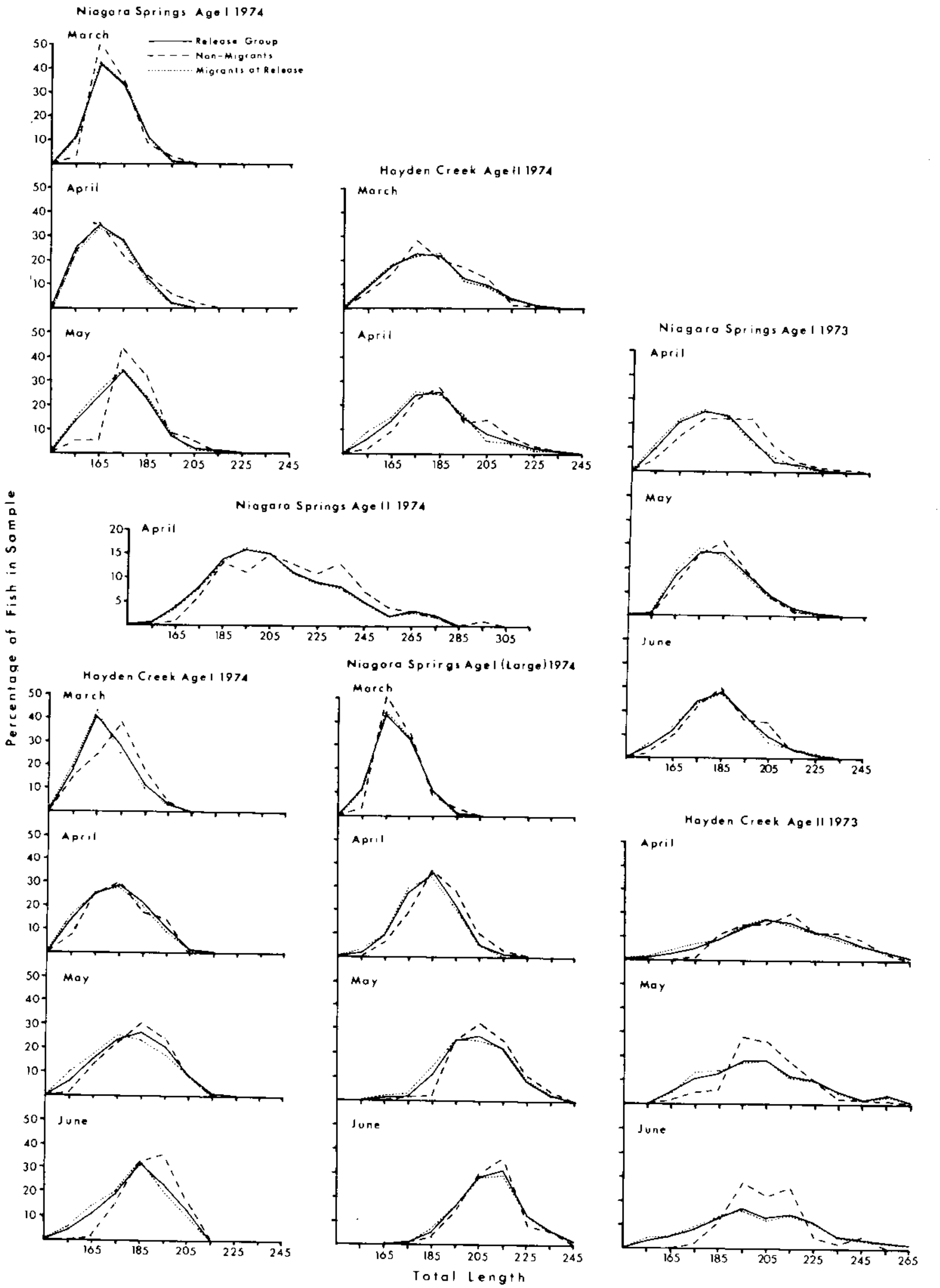

Figure 29. Length-frequency of hatchery steelhead trout of each release group as a whole, non-migrants, and migrants released into Big Springs Creek and recaptured at the weir, 1973-74.

Table 24. Mean length of the release group, non-migrants, and migrants at release of hatchery steelhead trout released into Big Springs Creek, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Total length (mm)															
	March release				April release				May release				June release			
Release group	At Release	Non-migrants	Migrants at release	F	At release	Non-migrants	Migrants at release	F	At release	Non-migrants	Migrants at release	F	At release	Non-migrants	Migrants at release	F
Hayden Creek age II 1974	180	180	181	2.01	184	182	189	8.90**[a]								
Hayden Creek age II 1973					210	209	213	0.91	203	203	204	0.04	205	205	205	0.01
Hayden Creek age I 1974	169	168	171	3.76*	172	172	176	2.96	181	179	184	6.64**	184	183	189	7.64**
Niagara-Pahsimeroi age II 1974					210	208	214	5.20**								
Niagara Springs age I 1974	169	169	170	0.18	168	167	178	22.09**	173	174	169	3.55*				
Niagara Springs age I large 1974	169	169	170	0.18	183	182	187	6.73**	203	202	206	4.63**	209	209	210	0.11
Niagara Springs age I 1973					178	177	184	12.70**	182	182	183	0.56	183	183	186	1.85

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

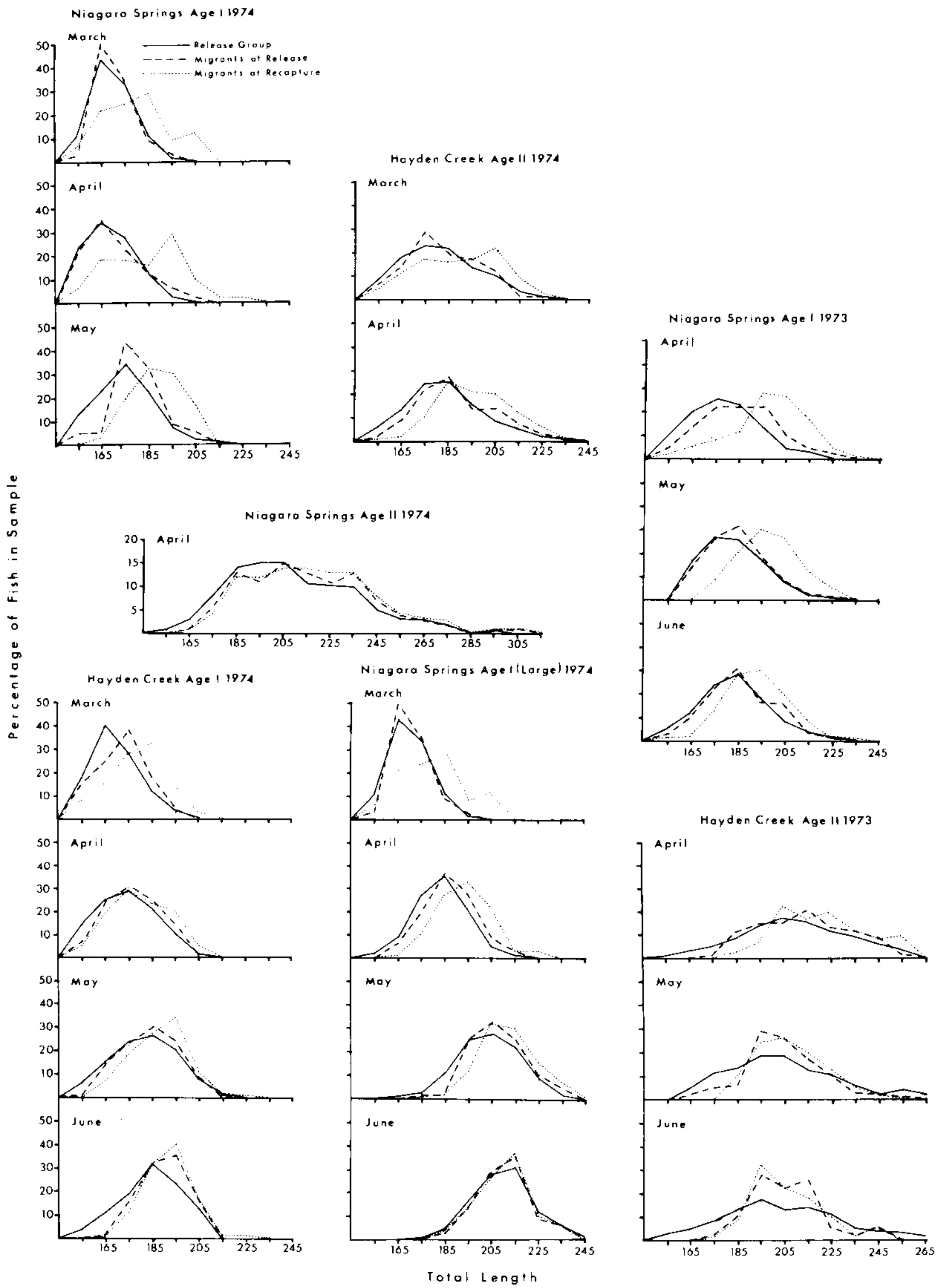

Figure 30. Length-frequency of the release group as a whole, migrants at release, and migrants at recapture of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973-74.

Table 25. Mean length of the release group, migrants at release, and migrants at recapture of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Total length (mm)															
	March release				April release				May release				June release			
Release group	At release	Migrants at release	Migrants at re-capture	F	At release	Migrants at release	Migrants at re-capture	F	At release	Migrants at release	Migrants at re-capture	F	At release	Migrants at release	Migrants at re-capture	F
Hayden Creek age II 1974	180	181	189	8.47**[a]	184	189	196	31.05**								
Hayden Creek age II 1973					210	213	222	9.94**	203	204	209	2.44	205	205	206	0.19
Hayden Creek age I 1974	169	171	178	31.05**	172	176	179	8.44**	181	184	188	19.22**	184	189	190	11.48**
Niagara-Pahsimeroi age II 1974					210	214	216	7.35**								
Niagara Springs age I 1974	169	170	180	26.11**	168	178	188	45.96**	173	169	183	25.43**				
Niagara Springs age I large 1974	169	170	180	26.11**	183	187	193	31.97**	203	206	211	16.61**	209	209	210	0.12
Niagara Springs age I 1973					178	184	196	89.60**	182	183	196	98.97**	183	186	191	14.52**

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 26. Percentage of each length group (150-169 mm, 170-199 mm, and ≥ 200 mm) of hatchery steelhead trout recaptured at the Big Springs Creek weir, 1973-74, ratio of the percentage recaptures for each length group with the percentage recaptured from the 150-169 mm length group as the divisor. Percentage recaptured was considered to be 1% when the number of fish released was 10 or more but with no recaptures.

	March release				April release				May release				June release				Composite ratio of April-May release groups
Release group	150-169 (mm)	170-199 (mm)	>200 (mm)	Ratio	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	Ratio	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	Ratio	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	Ratio	
Hayden Creek age II 1974																	
Number released	133	292	75	1.0:1.4:1.2	95	322	83	1.0:1.9:2.9									1.0:1.8:2.9
Percentage recaptured	12	17	15		18	32	52										
Hayden Creek age II 1973																	
Number released					22	156	368	1.0:24.0:27.0	38	324	405	1.0:2.2:2.6	52	250	359	1.0:6.0:7.0	1.0:13.1:14.8
Percentage recaptured					0	24	27		5	11	13		0	6	7		
Hayden Creek age I 1974																	
Number released	209	210	--	1.0:2.1:--	197	297	6	1.0:1.5:--	107	346	47	1.0:1.7:1.6	48	242	42	1.0:13.5:20.0	1.0:1.6:1.6
Percentage recaptured	11	23	--		13	20	--		29	48	45		2	27	40		
Niagara-Pahsimeroi age II 1974																	
Number released					40	357	603	1.0:2.7:3.6									1.0:2.7:3.6
Percentage recaptured					10	27	36										
Niagara Springs age I 1974																	
Number released	207	229	--	1.0:1.0:--	290	209	1	1.0:0.8:--	151	268	10	1.0:4.0:6.7					1.0:2.4:6.7
Percentage recaptured	7	7	--		11	9	100		3	12	20						
Niagara Springs age I large 1974													1	107	387	--:1.0:1.2	1.0:1.5:2.8
Number released	207	229	--	1.0:1.0:--	54	415	31	1.0:2.0:3.9	6	190	295	--:1.0:1.6	100	18	22		
Percentage recaptured	7	7	--		9	18	35		--	16	25						
Niagara Springs age I 1973																	
Number released					314	633	93	1.0:1.8:3.0	183	705	112	1.0:1.4:1.2	125	481	94	1.0:1.5:2.2	1.0:1.6:2.1
Percentage recaptured					8	14	24		17	23	21		10	15	22		
Average rates				1.0:1.4:1.2				1.0:5.0:8.1				1.0:2.1:2.7				1.0:3.5:4.9	1.0:3.5:4.9

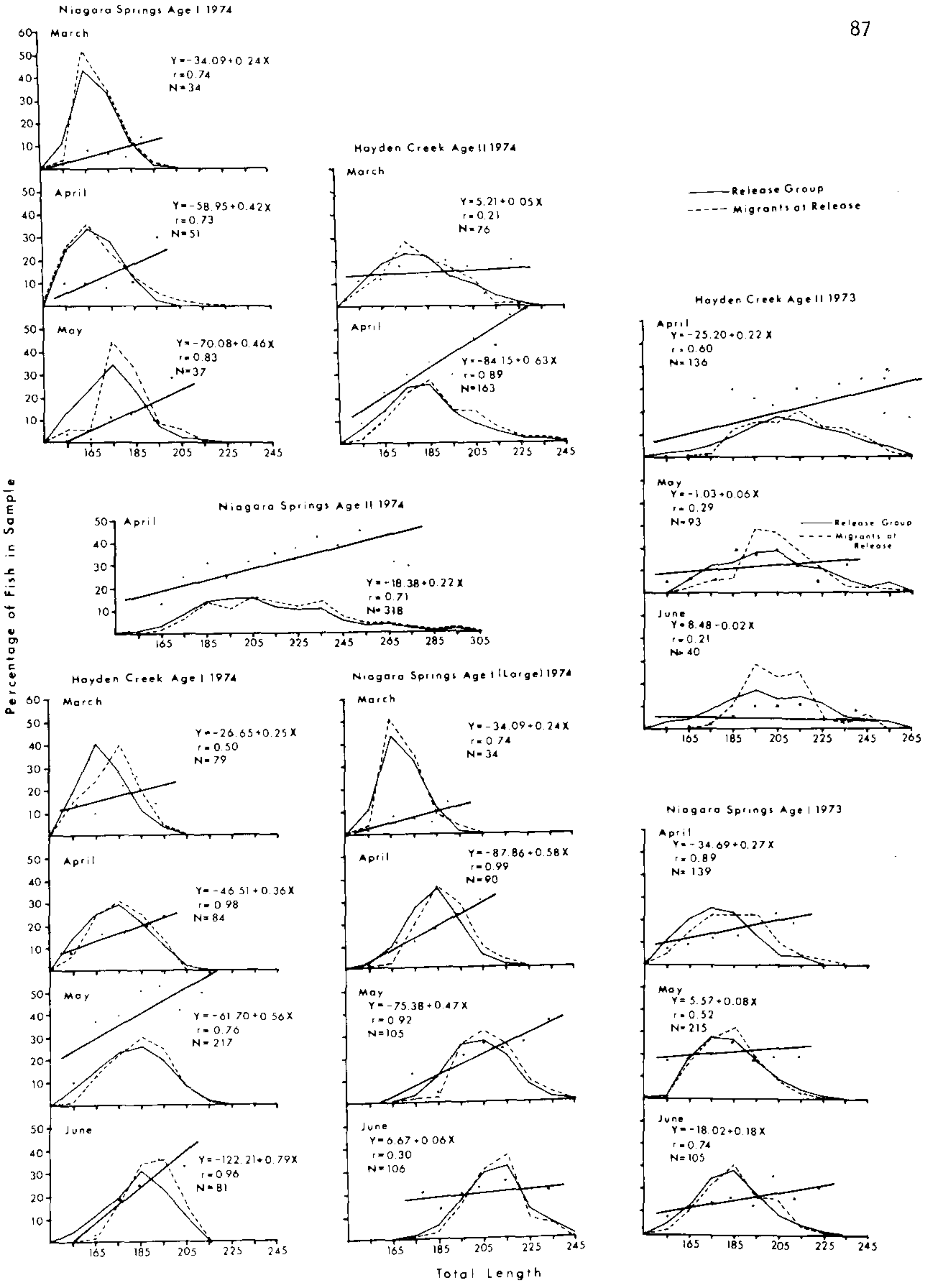

Figure 31. Length-frequency of the release group as a whole, the migrants when released and the relationship between length at release and percentage of the fish recaptured for hatchery steelhead trout of each 10 mm length class released into Big Springs Creek and recaptured at the weir, 1973-74.

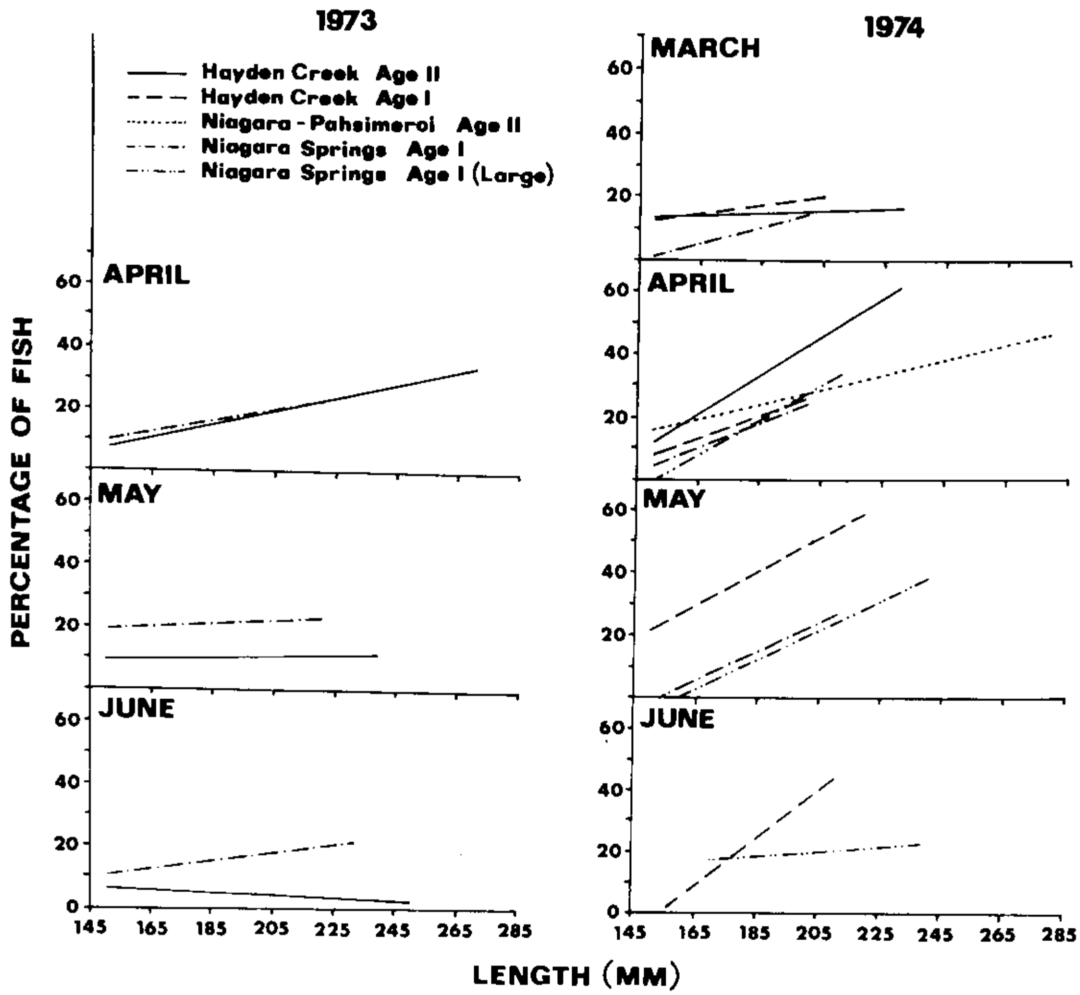

Figure 32. Regression lines for the relationship between length at release and the percentage of the hatchery steelhead trout released into Big Springs Creek about the first of each month that were recaptured at the weir, 1973-74.

The similarity of the regression lines of Niagara Springs age I versus age I large steelhead trout is an indication that the faster growth of the age I large fish did not result in more migrants from a particular size group of fish (Fig. 32). Fish of similar size from either group migrated at the same rate. Thus, growth rate alone does not seem to influence the parr-smolt transformation.

The mean number of days between release and migration was inversely related to length of hatchery fish at release for many of the test groups (Table 27). Generally, larger fish spent less time before migrating than smaller fish.

For release groups which migrated rapidly after release (Hayden Creek age I and Niagara - Pahsimeroi age II) or delayed migration till late in the migration season (Niagara Springs age I) in 1974, there was no significant relationship between length at release and mean days out (Table 27). For the Hayden Creek age II release group, which did not migrate from Big Springs Creek as rapidly as the Hayden Creek age I fish, there was a significant relationship between length at release and the mean number of days out. In 1973, the larger steelhead trout from both groups of Hayden Creek fish spent fewer days in Big Springs Creek between release and migration than smaller fish (Table 27).

Steelhead trout longer than 170 mm from the Niagara Springs age I large release groups migrated sooner than fish shorter than 170 mm or than fish from the Niagara Springs age I 1974 release groups (Table 27). The mean days out was not significantly different between the three length groups of Niagara Springs age I fish released in 1974. The faster growing Niagara Spring age I large fish spent less time before migrating than the slower growing Niagara Springs age I fish of the same length.

The mean number of days out for steelhead trout in the 150-169 mm length class did not change significantly from the March to June releases (Table 28). Generally, the mean number of days out for steelhead longer than 170 mm was less in the groups released later in the migration season.

Appearance

In this section we discuss the relationship, if any, between appearance at release and the rate of recovery of fish at the Big Springs Creek weir and the length of time spent in Big Springs Creek prior to migration.

Migration of hatchery steelhead trout released in March was largely independent of appearance at release because the appearance of the fish, which ultimately migrated, changed while they were in the stream (Fig. 33). For the April and May releases, 1.8 times more steelhead trout that were classified as intermediates and 2.6 times more that were classified as smolts when released, left Big Springs Creek than fish classified as parrs (Table 29). The high ratio of smolts and inter-

Table 27. Mean number of days out of three length groups (150-169 mm, 170-199 mm, and ≥ 200 mm of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Mean days out															
	March release				April release				May release				June release			
Release group	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F	150-169 (mm)	170-199 (mm)	≥ 200 (mm)	F
Hayden Creek age II 1974	45	48	55	0.47	41	33	26	3.76*[a]								
Hayden Creek age II 1973						31	26	6.38*	34	16	14	5.35**		5	2	5.70*
Hayden Creek age I 1974	30	53		0.27	22	22	31	0.13	19	16	14	1.32	13	8	8	1.12*
Niagara-Pahsimeroi age II 1974					22	21	20	0.20								
Niagara Springs age I 1974	54	52		0.04	47	50	48	0.08	38	32	30	0.30	14	9	7	2.62
Niagara Springs age I large 1974	54	52		0.43	60	35	25	3.96*		17	17	1.69	18	11	8	7.66**
Niagara Springs age I 1973					40	31	21	3.34*	35	32	25	6.48*				

[a]* = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 28. Mean number of days out for three length groups (150-169 mm, 170-199 mm, and ≥ 200 mm) of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \leq 0.05$).

	Length group and month of release														
	150-169 mm					170-199 mm					≥ 200 mm				
Release group	Mar	Apr	May	June	F	Mar	Apr	May	June	F	Mar	Apr	May	June	F
Hayden Creek age II 1974	45	41			0.21	48	33			15.44**[a]	55	43			24.23**
Hayden Creek age II 1973		34			----		31	16	5	55.41**		26	14	2	77.94**
Hayden Creek age I 1974	50	22	19	13	11.84**	53	22	16	8	102.12**		31	14	8	4.49*
Niagara-Pahsimeroi age II 1974		22			----		21			-----		20			----
Niagara Springs age I 1974	54	47	38		0.67	52	50	32		5.98**	---	48	30		1.37
Niagara Springs age I large 1974	54	47	38		0.67	52	35	20	9	16.60**	---	25	17	7	24.02**
Niagara Springs age I 1973		40	35	18	6.61*		31	32	11	48.03**		21	25	8	10.43**

[a] * = Significant $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

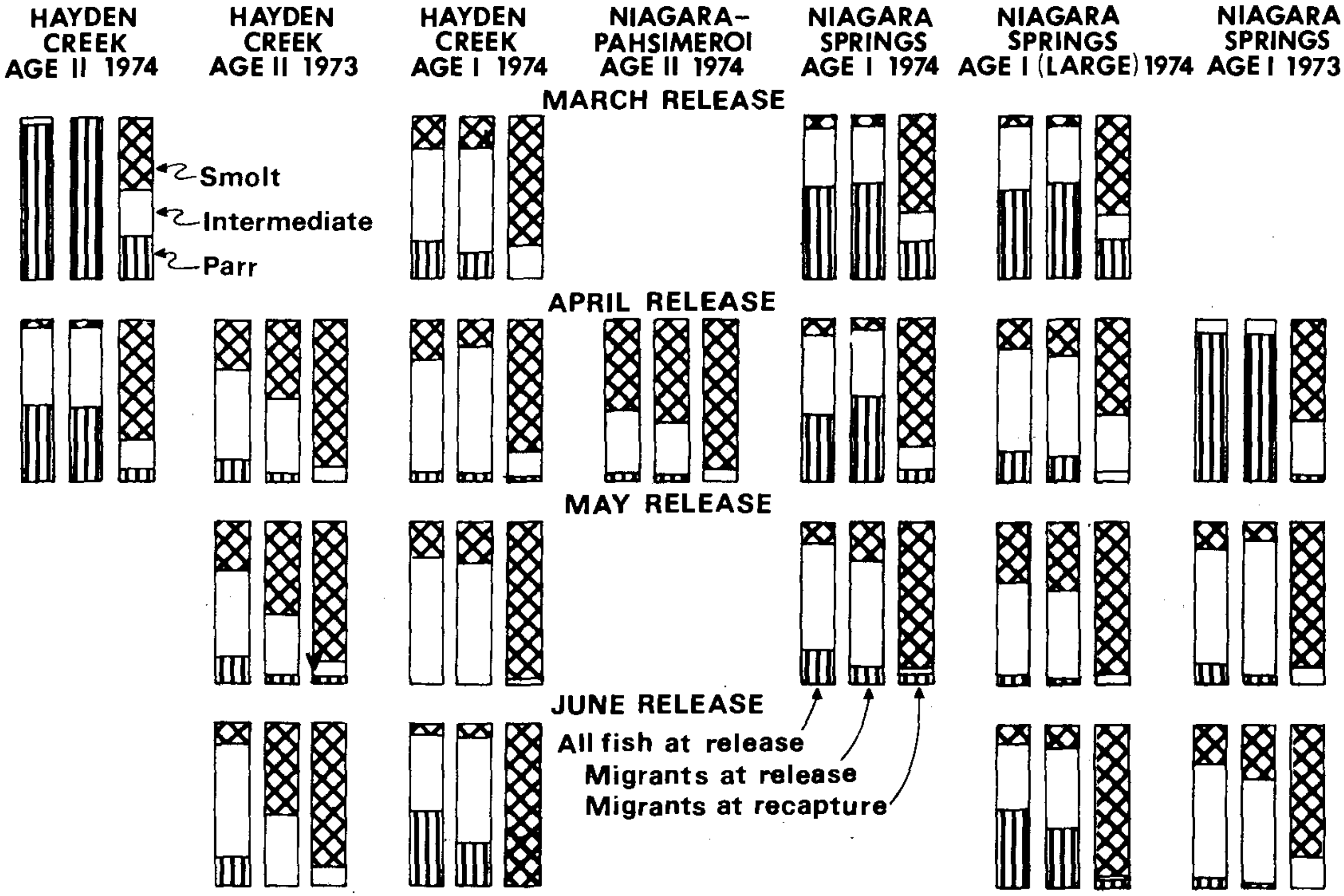

Figure 33. Percentage of hatchery steelhead trout classed as smolt, intermediate, or parr when released in Big Springs Creek, the migrants at time of release, and the migrants at time of recapture, 1973-74.

Table 29. Number of tagged hatchery steelhead trout released into Big Springs Creek and the percentage of each appearance group (smolt, intermediate, and parr) recaptured at the weir during 1973-74 from the March, April, May and June release groups. The ratio of the percentage recaptured was calculated by dividing the percentage recaptured for the intermediate and smolt groups by the percentage recaptured for the parr group. The percentage recaptured was considered to be 1% when the number of fish released was 10 or more, but with no recaptures.

	March release				April release				May release				June release				Composite ratio of April-May release groups
Release group	Smolt	Intermediate	Parr	Ratio	Smolt	Intermediate	Parr	Ratio	Smolt	Intermediate	Parr	Ratio	Smolt	Intermediate	Parr	Ratio	
Hayden Creek age II 1974																	
Number released	--	19	481	--:0.1:1.0	--	275	222	--:1.0:1.0									--:1.0:1.0
Percentage recaptured	--	0	16		--	32	32										
Hayden Creek age II 1973																	
Number released					153	329	64	5.1:2.5:1.0	217	416	119	8.0:6.0:1.0	75	471	115	32.0:3.0:1.0	6.6:4.2:1.0
Percentage recaptured					41	20	8		24	18	3		32	3	0		
Hayden Creek age I 1974																	
Number released	98	288	114	1.9:2.3:1.0	93	381	26	0.9:1.2:1.0	104	394	--	1.2:1.0:--	13	168	151	2.7:2.3:1.0	1.0:1.1:1.0
Percentage recaptured	15	18	8		14	18	15		50	41	--		38	33	14		
Niagara-Pahsimeroi age II 1974																	
Number released					546	435	19	1.7:1.3:1.0									1.7:1.3:1.0
Percentage recovered					36	28	21										
Niagara Springs age I 1974																	
Number released	22	203	275	0.7:0.8:1.0	34	365	201	0.5:0.8:1.0	50	294	85	3.2:1.8:1.0					1.8:1.3:1.0
Percentage recovered	5	6	7		6	9	12		16	9	5						
Niagara Springs age I large 1974																	
Number released	22	203	275	0.7:0.8:1.0	90	302	176	0.9:0.8:1.0	176	295	20	4.8:4.2:1.0	43	239	213	2.0:1.7:1.0	2.8:2.5:1.0
Percentage recovered	5	6	7		21	19	24		24	21	5		30	26	15		
Niagara Springs age I 1973																	
Number released					--	97	942	--:1.2:1.0	137	761	100	1.4:1.5:1.0	152	502	45	11.0:3.5:1.0	1.4:1.4:1.0
Percentage recovered					--	15	13		21	22	15		22	14	2		
Average rates				1.1:1.0:1.0				1.8:1.3:1.0				3.7:2.9:1.0				11.9:3.5:1.0	2.6:1.8:1.0

mediates to parrs among the fish recaptured from the June releases (Table 29) is an indication that few of the fish classified as parrs when released late in the migration season migrate to the ocean.

Hatchery steelhead trout classified as smolts and intermediates appeared to migrate from Big Springs Creek earlier than parrs in a few cases (Table 30), but the differences in the mean number of days out between each of the appearance groups was not significant except for the age I steelhead trout released during May from Niagara Springs Hatchery. The mean number of days between release and migration for steelhead trout classified as smolts, intermediates, and parrs decreased significantly from the March releases to the June releases (Table 31), but the mean days out was similar for fish released at the same time whether classified as parr, intermediate or smolt.

Age at Release

In this section we evaluate the effect of one versus two years of hatchery rearing on parr-smolt transformation and seaward migration of hatchery steelhead. The onset of parr-smolt transformation was earlier for age I than age II steelhead trout from the Hayden Creek Station based on appearance (Fig. 4), coefficient of condition (Fig. 6), NaK-ATPase activity (Fig. 8), and saltwater tolerance (Table 9). We recaptured equal percentages of Hayden Creek age I and age II steelhead trout released in early March, but more of the age II fish from the April release (Table 12). The age II fish from Hayden Creek were larger than age I fish as well as being older, thus the larger percentage recovery was probably due in part to their larger size. The regression lines for the relation between length at release and percentage recaptured (Fig. 32) were divergent, with a higher percentage recovery for all length classes of age II fish versus age I fish of the April 1974 release.

The timing of migration (Table 15) and migration pattern (Fig. 25), from Big Springs Creek of the Hayden Creek age II and age I steelhead trout was similar for the March releases, but different for the April releases. Age I fish released the first of April migrated approximately two weeks earlier than the age II fish; median migration date was April 14 for age I fish versus April 29 for age II fish. The duration of migration of the age II fish was 6 days shorter than for age I fish. An estimated $3 \pm 0\%$ of the age II March release and $12 \pm 1\%$ of the April release were in Big Springs Creek in July 1974 (Table 16). None of the age I Hayden Creek steelhead trout released in March or April were recovered in July 1974, perhaps the result of differential in-stream mortality between the two age groups.

The onset of parr-smolt transformation in Niagara Springs steelhead trout reared for two years (the first year at Niagara Springs Hatchery and the second year in the pahsimeroi pond) was earlier (March) than for age I steelhead (April or May) from Niagara Springs Hatchery (regular sized or the large, faster growing fish) or age I fish from Hayden Creek Station (Fig. 4, 6 and 8, Table 9). Reversion to parr of age II fish from the Pahsimeroi pond also occurred earlier.

Table 30. Mean number of days out for the three appearance groups (smolt, intermediate, and parr) of hatchery steelhead trout released into Big Springs Creek and recaptured at the weir, 1973-74. Means underlined by the same continuous line are not significantly different from each other ($P \leq 0.05$).

Release group	March release				April release				May release				June release			
	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F	Smolt	Intermediate	Parr	F
Hayden Creek age II 1974	—	--	50	---	32	30	34	0.59								
Hayden Creek age II 1973					14	16	20	0.92	14	16	20	0.92	3	4	--	0.38
Hayden Creek age I 1974	61	50	50	0.96	20	23	19	0.20	14	17	22	1.49	8	8	8	0.15
Niagara-Pahsimeroi age II 1974					21	20	19	0.26								
Niagara Springs age I 1974	53	61	48	0.65	30	45	53	1.32	32	32	35	0.08				
Niagara Springs age I large 1974	53	61	48	0.65	36	34	33	0.62	18	17	25	0.17	7	7	9	1.13
Niagara Springs age I 1973					48	29	31	0.26	26	32	36	6.56**[a]	10	11	1	0.69

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Table 31. Mean number of days out for three appearance groups (smolt, intermediate, and parr) of hatchery steelhead trout released into Big Springs Creek during March, April, May or June and recaptured at the weir, 1973-74. Means underlined by the same continuous or discontinuous line are not significantly different from each other ($P \geq 0.05$).

	Mean days out														
	Smolt					Intermediate					Parr				
Release group	Mar	Apr	May	June	F	Mar	Apr	May	June	F	Mar	Apr	May	June	F
Hayden Creek age II 1974		32			-----		30			-----	48	34			13.04**[a]
Hayden Creek age II 1973		28	14	3	72.17**		28	16	4	43.95**		25	20	---	2.48
Hayden Creek age I 1974	61	20	14	8	48.73**	50	23	17	8	70.45**	50	19	22	8	11.14**
Niagara-Pahsimeroi age II 1974		21			-----		20			-----		19			----
Niagara Springs age I 1974	53	30	32		0.86	61	45	32		6.47**	48	53	35		0.78
Niagara Springs age I large 1974	53	36	18	7	10.20**	61	36	18	7	48.58**	20	34	25	9	15.69**
Niagara Springs age I 1973		48	26	10	21.80**		29	32	11	88.20**		31	36	1	1.40

[a] * = Significant at $P \leq 0.05$ and ** = significant at $P \leq 0.01$.

Niagara - Pahsimeroi steelhead trout reared for two years migrated from Big Springs Creek in larger numbers (Table 12) and earlier (Fig. 25) than age I or age I large fish released from Niagara Springs Hatchery at the same time. Most of the Niagara - Pahsimeroi age II steelhead trout released the first of April migrated from Big Springs Creek within a month after release (Fig. 25). Age I fish from the Niagara Springs Hatchery had a delayed migration from Big Springs Creek. The median migration date was April 18 for age II fish compared to May 27 for age I and May 10 for age I large steelhead trout. The timing of migration of the Niagara - Pahsimeroi age II steelhead trout at Ice Harbor Dam in 1974 was only one week earlier than the Niagara Springs age I fish (Fig. 20).

We recaptured 32% of the Niagara - Pahsimeroi age II fish released into Big Springs Creek during April compared to 10% of the age I and 18% of the age I large fish (Table 12). The larger number of age II fish recovered was not due entirely to their larger size if differences in the length-percentage recaptured regression lines (Fig. 32) for the three groups have any significance. A higher percentage of the small age II steelhead trout from the Pahsimeroi pond and from Hayden Creek station migrated than did similar size age I fish from Niagara Springs Hatchery and Hayden Creek Station. The difference in percentage of migrants between the age II steelhead trout from the Pahsimeroi pond and Hayden Creek versus the Niagara Springs age I fish may have been caused by the constant 15 C water temperature at the Niagara Springs Hatchery which may have inhibited parr-smolt transformation. An estimated 14 $\pm$ 1% of the age II Niagara Springs April release fish were in Big Springs Creek in July 1974 compared to 5 $\pm$ 0% of the Niagara Springs age I and 2 $\pm$ 0% of the Niagara Springs age I large fish (Table 16).

The ratio of Niagara Springs age I to age II steelhead trout migrants of the April release recovered before June 1 was 1.0:4.6. The ratio of Niagara Springs age I large to age II steelhead trout migrants was 1.0:1.9. The ratio of Hayden Creek age I to age II steelhead trout migrants of the April release was 1.0:1.5.

Hayden Creek Versus Niagara Springs Hatcheries

Water temperature is an important factor influencing the physiological changes at the time of parr-smolt transformation and migration behavior of anadromous fish. Foerster (1937) and Fontaine (1954) observed that smolting and migration were earlier for Atlantic salmon if the average water temperatures were higher in the preceding months. Eales (1964) found increased thyroid activity in steelhead trout smolts depended on both increasing temperature and photoperiod. Pinder and Eales (1969) noted that seasonal changes in buoyancy in Atlantic salmon smolts (smolts being more buoyant than parr) were accelerated by an increase in temperature. Temperature also increased the deposition of guanine and hypoxanthine (silvering) in the skin of these same fish (Johnston and Eales 1968).

Wagner (1974a) reported that temperature had two measureable effects on parr-smolt transformation and migration in winter steelhead trout. Winter steelhead trout reared under a variable temperature cycle (6 to 18 C) moved downstream in larger numbers and in fewer days than fish reared at a constant temperature (12.4 C). Zaugg et al. (1972) and Adams et al. (1973) found that summer steelhead trout held in 10 C or less water had increased gill NaK-ATPase activity in the spring whereas fish held in water of 15 C and 20 C did not. Speculation that steelhead trout whose NaK-ATPase activity was inhibited, when reared in warmer water temperatures, might not migrate to the ocean was confirmed by Zaugg and Wagner (1973). They concluded that 13 C was the upper temperature which would still allow normal parr-smolt transformation and downstream migration of juvenile steelhead trout. From the data of Adams et al. (1973), fish reared at 15 C and then transferred to 6-10 C water 6-8 weeks before the migration season should go through parr-smolt transformation as well as fish reared at a lower temperature.

We compared only the Hayden Creek age I and the Niagara Springs age I fish released in 1974 to evaluate the effects of water temperature on parr-smolt transformation and seaward migration of steelhead trout. The age I steelhead trout from the Hayden Creek Station were reared at 12 C compared to 15 C for fish reared at Niagara Springs Hatchery. Both groups were Clearwater River stock of the 1973 year class and were of similar size when released into Big Springs Creek.

More of the fish from the Hayden Creek Station were smolts and intermediates in appearance when released than those from Niagara Springs Hatchery (Fig.4). Fish reared in the warmer water at Niagara Springs Hatchery were less silvery than fish reared in the cooler water at Hayden Creek Station. Less than half the age I fish from Niagara Springs Hatchery had developed the full smolt appearance by the date of release.

Steelhead trout from the Hayden Creek Station had the characteristic vernal decline in the coefficient of condition associated with parr-smolt transformation (Fig. 6), but the decline was not as pronounced for Niagara Springs age I fish. The mean coefficients of condition of the Niagara Springs age I fish were similar to those of precocious mature males that did not become smolts.

The NaK-ATPase activity of age I steelhead trout from Hayden Creek Station increased during the migration season, but did not increase in age I fish reared at Niagara Springs Hatchery (Fig. 8). The lack of a seasonal increase in NaK-ATPase activity leads us to suspect that few steelhead trout reared in the warmer water at Niagara Springs Hatchery complete the parr-smolt transformation while at the hatchery.

Juvenile steelhead trout from the Hayden Creek Station were better adapted for saltwater than fish from Niagara Springs Hatchery. During March and April, 15% and 10%, respectively, of the Hayden Creek age I steelhead trout survived the 10 day test in saltwater (Table 9). None of the Niagara Springs age I steelhead trout survived the 10-day salt water exposure, with most dying the first day.

A higher percentage of the age I steelhead trout from Hayden Creek Station migrated out of Big Springs Creek than the age I fish from Niagara Springs Hatchery. We recaptured 16% of the March release, 17% of the April, 43% of the May, and 24% of June release of Hayden Creek age I steelhead trout (Table 12). In comparison, the percentage recovery of the March, April, and May releases of Niagara Springs age I steelhead was 7%, 10%, and 12%, respectively.

Many of the Hayden Creek age I steelhead trout released into Big Springs Creek migrated immediately after release (Figs. 16 and 25). The median migration days for fish released the first of March was 58 days, 14 days for the April release, 16 days for the May release, and 7 days for fish released the first of June (Table 15). Migration was virtually complete by the first of June with 97% of the migrants from the March release, 99% from the April release, and 95% from the May release having passed the Big Springs Creek weir.

The migration of age I steelhead trout from Niagara Springs Hatchery occurred over a longer period and later into June than for the Hayden Creek fish (Figs. 16 and 25). The median migration days for the March, April, and May releases were 60, 58, and 39 days, respectively (Table 15). Only the fish from the March release group completed migration by the first of June. Of the total number of migrants, 91% of the March release were recaptured at the Big Springs Creek weir trap by June 1, 71% of the April release, and 38% of the May release.

The timing of migration for steelhead trout from Hayden Creek Station and Niagara Springs Hatchery was similar for fish released in March (Fig. 16), but Niagara Springs fish of the April release were 6 weeks later and fish of the May release 3 weeks later in migrating from Big Springs Creek than Hayden Creek fish.

A higher percentage of Hayden Creek fish from all length groups were recaptured at the weir than Niagara Springs fish. More of the small fish (less than 170 mm) reared in the colder water at the Hayden Creek Station migrated and they moved downstream earlier than fish reared at Niagara Springs Hatchery.

Cold Water Conditioning

In this section we evaluate the effects on migration of conditioning Niagara Springs steelhead trout in colder water (less than 13 C) before release. On the first of March, first of April, and April 15, 1974, we transferred groups of Niagara Springs age I large steelhead trout from Niagara Springs Hatchery to holding tanks at the Hayden Creek Station supplied with water from Hayden Creek (2-9 C).

The five groups of marked steelhead trout we released into Big Springs Creek had been conditioned in the colder water for 2-8 weeks. The first group of fish was released March 30 after 4 weeks of conditioning and is designated as the March-April group. Three groups were marked and released on April 27 and 28. The first group had been conditioned for 8 weeks (March-May), the second for 4 weeks (April-May), and the third group for two weeks (April 15-May). We released the last group June 1 after 4 weeks of conditioning (May-June).

Conditioning steelhead trout in cold water for four weeks before release on March 30 did not increase the percentage of fish which migrated downstream (Table 32). Niagara Springs age I large steelhead trout released March 30 had as many migrants (18% recaptured) as fish of the same original group that were conditioned in cold water during March at the Hayden Creek Station (19% recaptured). The percentages of the two groups recovered before June 1 (17% versus 16%), median migration dates (May 10 versus May 8), mean number of days between release and migration (35 versus 36 days), and timing of migration (Figs. 34 and 35) were similar (Table 32).

Fish released into Big Springs Creek the first of May, after being conditioned for 2, 4, or 8 weeks, migrated in equal or larger numbers than comparable unconditioned groups (Table 32). Steelhead trout conditioned for 8 weeks (March-May) had a similar percentage of migrants (19%) as the unconditioned May release group (21%). Migration of the March-May fish started the first two weeks after release, but then slowed for two weeks before resuming during the month of June (Fig. 35). By the first of June, we had recaptured 12% of the March-May conditioned fish (63% of those recaptured) and 18% of the unconditioned May release (36% of those recaptured). The median migration dates of the two groups were May 8 (March-May) and May 13 (May). The mean number of days out (22 versus 18) was similar for the conditioned and unconditioned groups.

Conditioning steelhead trout for 2 or 4 weeks (April-May and April 15-May) before release the first of May increased the percentage of fish recaptured at the Big Springs Creek weir, but many of the fish migrated after June 1. We recovered 35% of the April-May conditioned fish and 30% of the April 15-May fish compared to 21% of the unconditioned fish released the first of May (Table 32). By June 1, we had recaptured 43% of the April-May fish that were recaptured, 70% of the April 15-May fish, and 86% of the unconditioned fish released the first of May (Figs. 34 and 35). The median migration dates for the April-May and April 15-May conditioned fish were June 1 and May 25, respectively, compared to May 13 for the unconditioned fish released the first of May. The mean number of days between release and migration was 34 for the April-May fish, 28 for the April 15-May fish, and 18 for the unconditioned fish.

The steelhead trout conditioned for 4 weeks before release June 1 (May-June) had fewer migrants (9% recaptured) than the unconditioned fish released June 1 (21% recaptured), but the median migration days, duration of migration and the mean number of days out were similar for both groups (Table 32).

Table 32. Migration data of Niagara Springs age I large, and Niagara Springs age I large steelhead trout conditioned 2, 4, and 8 weeks in cold water before release into Big Springs Creek in 1974, including release date, number released, percentage recovered, median migration date, median migration days, duration, mean days out, and residual index.

	Niagara Springs age I large				Niagara Springs age I large conditioned				
	March	April	May	June	March-April	March-May	April-May	April 15-May	May-June
Release date	3/2	3/30	4/27	6/1	3/30	4/27	4/27	4/28	6/1
Number released	500	500	491	495	500	83	348	463	127
Percentage recovered									
(total)	7	18	21	21	19	19	35	30	9
(1-15 days)	2	6	10	21	6	11	4	5	9
(1-30 days)	2	8	17	21	9	12	11	17	9
(Before June 1)	6	17	18	--	16	12	15	21	-
Median migration date	5/1	5/10	5/13	6/9	5/8	5/8	6/1	5/25	6/10
Median migration days	60	41	16	8	39	11	36	27	9
Duration (days)	75	50	36	10	65	37	34	42	10
Mean days out	53	35	18	8	36	22	34	28	9
Percentage residual	-	3	23	60	-	-	4	18	11
Mean length (mm)	169	183	203	218	177	170	184	198	206

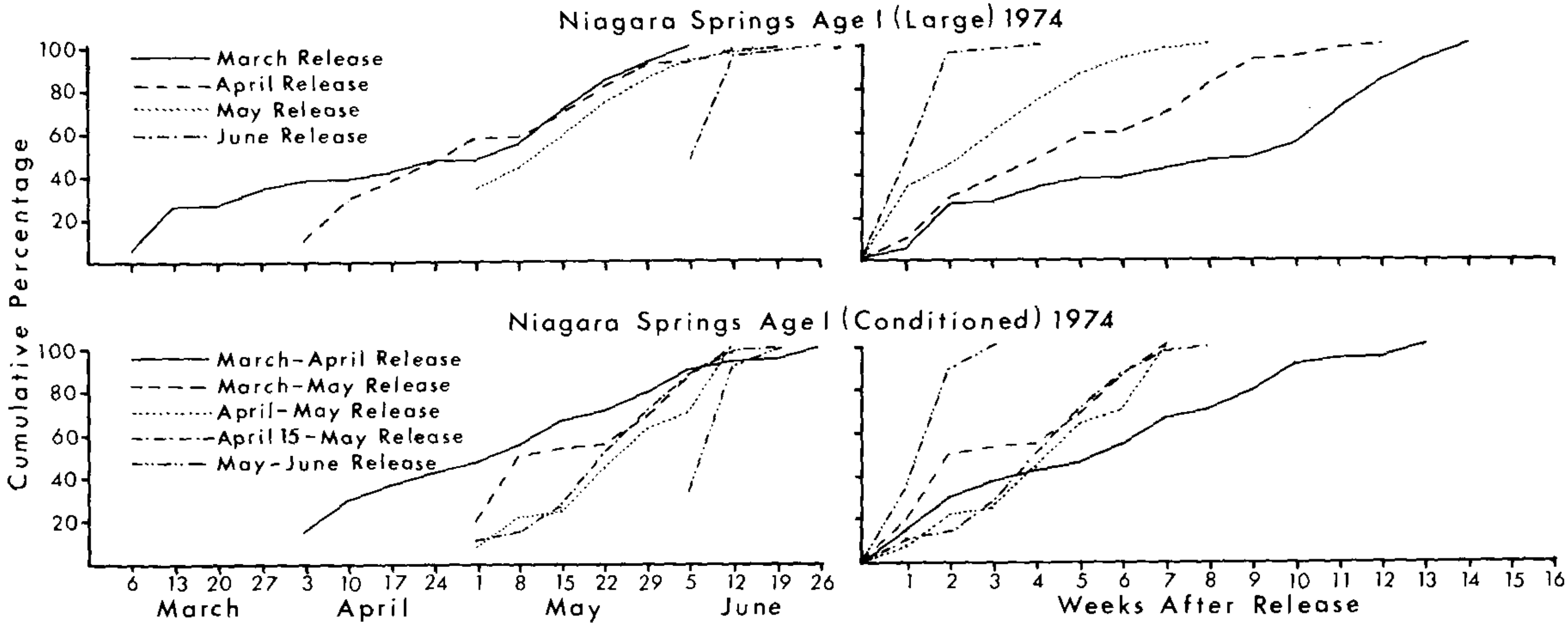

Figure 34. Cumulative catch curves for Niagara Springs age I large and Niagara Springs age I large conditioned (2, 4, and 8 weeks in cold water) steelhead trout released into Big Springs Creek and recaptured at the weir, 1974.

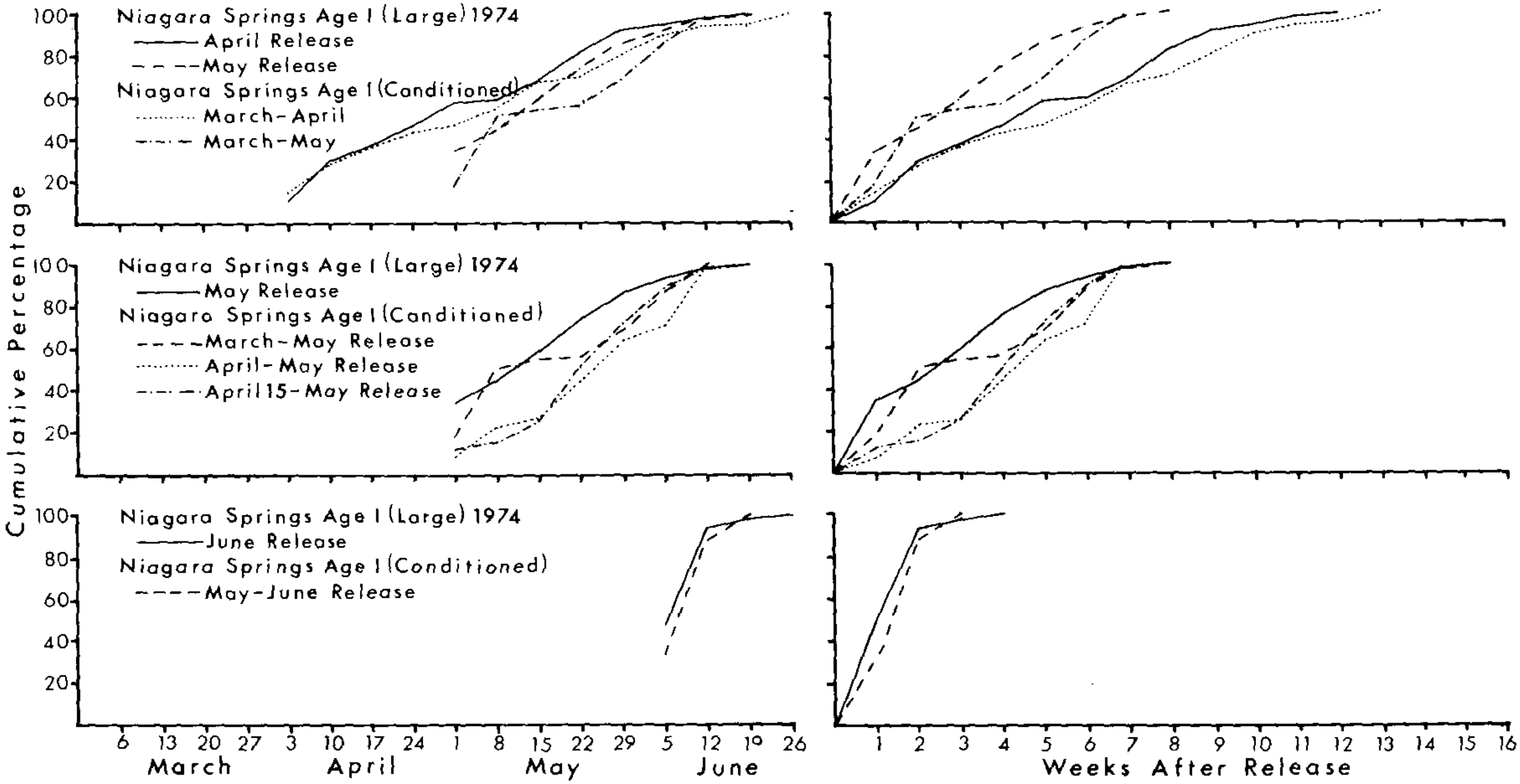

Figure 35. Comparison of cumulative catch curves for Niagara Springs age I large and Niagara Springs age I large conditioned (2, 4, and 8 weeks in cold water) steelhead trout released into Big Springs Creek and recaptured at the weir, 1974.

The unconditioned fish were larger when released than the conditioned fish because the conditioned fish, although from the same group, were held in colder water 2-8 weeks prior to release. On the basis of length alone, we would have expected more migrants from the unconditioned fish, but such was not the case. A larger percentage of the conditioned fish were recaptured than the unconditioned fish for all length groups of fish released in April and May (Fig. 36).

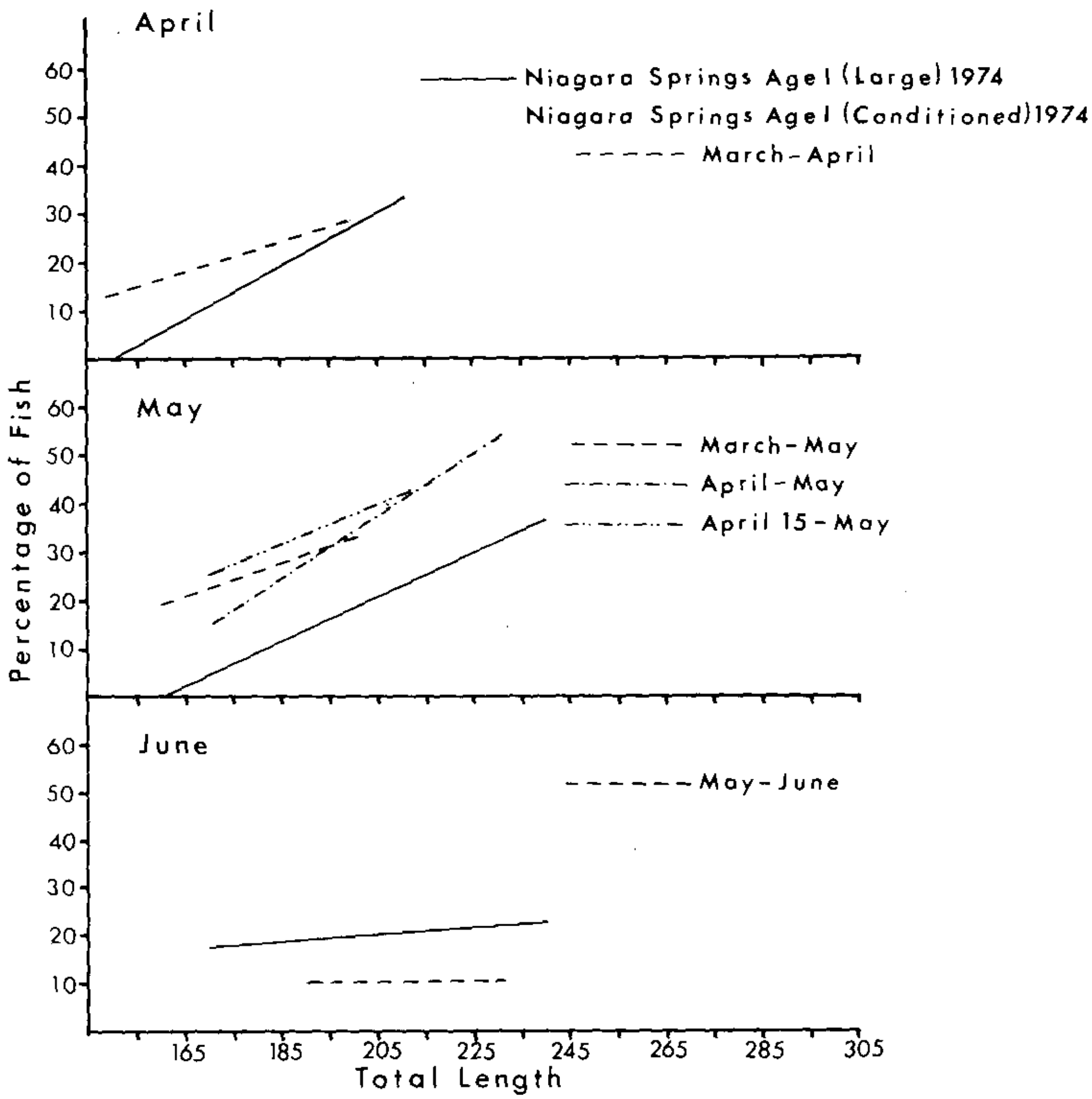

Figure 36. Relationship between length and percentage recovery of Niagara Springs age I large and Niagara Springs age I large conditioned steelhead trout (2, 4, and 8 weeks in cold water) released into Big Springs Creek and recaptured at the weir, 1974.

DISCUSSION

Changes in appearance, coefficient of condition, NaK-ATPase activity, saltwater tolerance, and migration behavior occurred during the transformation from parr to smolt of juvenile summer steelhead trout. The cryptic-colored, stream bottom dwelling parr became a silvery pelagic fish at least partially adapted to the marine environment by the time seaward migration commenced. Parr-smolt transformation in wild and hatchery summer steelhead trout was size dependent and seasonal in occurrence. Summer steelhead trout must reach a total length of 140 - 160 mm before they will become smolts and migrate to the sea. Wild steelhead trout spend one to four years in streams before migrating seaward, but steelhead reared in a hatchery can reach the critical length for migration in one year if water in the hatchery is warm enough for accelerated growth. Seaward migration of wild and hatchery summer steelhead trout occurred mainly during April and May with the peak of migration in early to mid-May. Summer steelhead trout that do not migrate to the ocean revert to parr and readapt to the freshwater environment.

Changes in the coefficient of condition, NaK-ATPase activity, and, to a lesser extent, appearance were useful in assessing the extent of parr-smolt transformation prior to migration. Saltwater tolerance was a poor index of parr-smolt transformation in the fish we tested.

Appearance alone was not an infallible index of parr-smolt transformation, because all fish became more silvery at the onset of parr-smolt transformation, including those which did not undergo changes in coefficient of condition or NaK-ATPase activity. Appearance of hatchery steelhead trout released near the peak of migration was related to migratory behavior. Fish classified as smolts or intermediates were more likely to migrate than fish classified as parrs. Fish classified as parrs which did migrate, had the same timing of migration as fish classified as smolts or intermediates.

The coefficient of condition did not decrease significantly for all groups of hatchery or wild fish during the spring migration season. The decrease in coefficient of condition observed in other stocks of fish (Fessler and Wagner 1967) may not be as pronounced in fish as far from the ocean as the ones we studied or in those reared in hatcheries with relatively warm (15 C) water.

NaK-ATPase activity increased during parr-smolt transformation and migration for all fish we studied, except the Niagara Springs age I fish reared in (15 C) water. Since the Niagara Springs age I groups had the fewest migrants in Big Springs Creek, the lack of increase in gill NaK-ATPase activity was an indication that those fish had not progressed as far as the other fish in the transformation from parr to smolt.

Few of the fish we tested for saltwater tolerance survived and we believe the seawater challenge was a poor index of parr-smolt transformation. The lack of correlation between survival in our saltwater tests (highest in March and April) and the normal time for steelhead trout to enter the sea (May-June) leads us to question the validity of our saltwater tests. Saltwater tolerance of the upriver fish stocks probably increases as the fish migrate seaward, so that high mortality among hatchery fish at time of release might not be unusual. Conte and Wagner (1965) and Wagner (1974b) concluded that parr-smolt transformation and saltwater adaptation in winter steelhead trout were two distinct and unrelated physiological processes, but that loss of saltwater tolerance may be correlated with reversion to parr.

Steelhead trout migrate to the sea when they are in the proper physiological condition (have undergone parr-smolt transformation) and at a time when the appropriate external stimuli are present. Wagner (1974a) suggested that parr-smolt transformation was controlled by an endogenous rhythm but synchronized by photoperiod because of the migratory behavior and smolt-like characteristics of fish reared in the dark and constant temperature. He believed that photoperiod was the main priming factor which set the timing for the onset of parr-smolt transformation. Temperature did not appear to influence the onset of parr-smolt transformation but did affect the magnitude and duration of migration of the fish Wagner (1974a) studied.

External factors which may act as releasers that initiate migration are temperature, light intensity, river discharge, and meteorological factors (Baggerman 1960). Bjornn (1971) examined data on temperature, food abundance, stream flow, cover, and population density in relation to seaward migration of wild summer steelhead trout from Big Springs Creek and the Lemhi River, and concluded that none of the factors appeared necessary to stimulate or release the seaward migration response. Movement frequently coincided with changes in water temperature and river discharge, but not consistently. He concluded that stream flow and temperature might modify the timing and duration of migration, but they were not the main factors that initiated parr-smolt transformation and set the basic timing for migration.

Hatchery steelhead trout should be released at a time that will allow them to reach the ocean in May or early June. Steelhead trout held at the hatchery until the start of the normal period of seaward migration were more likely to migrate than fish released earlier or later in the season. Mid April appears to be the optimum time of release for age I steelhead trout from Hayden Creek Station and Niagara Springs Hatchery.

Wagner et al. (1963) in evaluating adult returns to the Alsea River, Oregon, found that length of smolts at release was more important than time of release. Length at release was an important factor governing parr-smolt transformation and downstream migration of the wild and hatchery summer steelhead trout we studied. The changes associated with parr-smolt transformation were more pronounced and occurred earlier in the larger fish than in the smaller fish.

Wild and hatchery summer steelhead trout must be at least 140-160 mm total length for parr-smolt transformation and seaward migration to occur. The 140 - 160 mm length should not be viewed as a threshold length, where all fish that long or longer will become smolts, particularly for steelhead trout reared in hatcheries. The relation between length at release and percentage migrating (recaptures at the weir) from each length group was consistently linear (up to 210 mm) for the fish we tested (Fig. 31). More of the larger fish migrated than the smaller fish.

The two-year old hatchery steelhead trout we studied started the parr-smolt transformation, migrated out of Big Springs Creek more rapidly, and in larger numbers than fish reared for one year; due in part, to the larger size of the age II fish. The ratio of age I large steelhead trout from Niagara Springs Hatchery to the Niagara - Pahsimeroi age II fish of the April 1974 release which migrated before June 1 was 1:1.9. The ratio of migrants recovered before June 1 for the Niagara Springs age I versus the age II fish was 1:4.6. Hayden Creek age I versus Hayden Creek age II steelhead trout released in April of 1974, had a ratio of 1:1.5.

One of the potential disadvantages of a two year rearing program for steelhead trout is the tendency of males to mature if reared too rapidly for two years. We avoided tagging maturing males, but if 20% of the males were to mature precociously and not migrate, the ratio of Niagara Springs age I large to age II fish would have been 1:1.5 rather than 1:1.9. The ratio of Niagara Springs age I to age II fish would have been 1:3.6 rather than 1:4.6.

More age II steelhead trout of a given length migrated seaward than age I fish of that same length so that age at release may have an effect on seaward migration (Fig. 31). About 40% of the difference in percentage of fish recaptured between age I and age II hatchery steelhead trout may have been due to age. For every Hayden Creek age I or Niagara Springs age I fish of a given length which migrated from Big Springs Creek, 1.2 Hayden Creek age II or 1.3 Niagara Springs age II fish migrated.

On the basis of Niagara Springs age I and Niagara - Pahsimeroi age II steelhead trout released into the Pahsimeroi River during April 1974 (Reingold 1975) and recaptured at Ice Harbor Dam, the timing of migration was 1-week earlier for the age II fish and the ratio of recapture was 1:1.5 rather than the 1:4.6 we observed for fish released into Big Springs Creek. The adults from the 1974 releases returned to the Pahsimeroi River in 1976 and 1977 with one marked adult from the age I fish and 18 from the age II fish,[1/] a ratio of 1:18. The age II fish released in 1974 were Pahsimeroi stock while the age I fish were Clearwater River stock, a factor to consider along with the difference in age and length when evaluating the benefits of one versus two years of hatchery rearing.

[1/] Personal communications, Melvin Reingold, Salmon, Idaho.

The relatively warm water (15 C) used for rearing steelhead trout at Niagara Springs Hatchery may have inhibited parr-smolt transformation and migration. NaK-ATPase activity did not increase and the coefficient of condition of steelhead trout reared at Niagara Springs Hatchery did not decrease as they did for fish reared at Hayden Creek Station or in the Pahsimeroi pond. A smaller percentage of the fish from Niagara Springs Hatchery migrated from Big Springs Creek and they migrated later in the season than fish from Hayden Creek Station or the Pahsimeroi pond.

Since steelhead trout reared in the relatively constant temperature water (11-12 C) at Hayden Creek Station went through the normal parr-smolt transformation changes, neither a diurnal nor a seasonal change in temperature appears necessary for parr-smolt transformation to occur.

Conditioning steelhead trout from the Niagara Springs Hatchery in colder water for 2-8 weeks increased the number of migrants in some groups but the migration was delayed. We had difficulty maintaining the health of the fish in the circular tanks for two months during the cold water conditioning and thus we have some reservations about the results of our cold water conditioning tests. Steelhead trout reared in colder water (10 C) at the Hayden Creek Station did not have the delay in migration experienced by the cold water conditioned fish or the fish released directly from Niagara Springs Hatchery. Perhaps the 4-8 weeks of conditioning was not long enough to fully activate the physiological changes associated with parr-smolt transformation so that migration would occur at the proper time.

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