MIGRATORY CHARACTERISTICS OF JUVENILE SPRING CHINOOK SALMON IN THE WILLAMETTE RIVER

COMPLETION REPORT

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EXECUTIVE SUMMARY

- Rearing treatments (standard production, triple density with oxygen, and third pass in the Michigan series with oxygen) at Willamette Hatchery did not measurably affect migratory ability or behavior of spring chinook salmon smolts over a 280 km outmigration in the Willamette River.

- Overall survival of radio-tagged Willamette Hatchery outmigrating spring chinook over 280 km in the Willamette River is excellent, with most conservative estimates ranging up to 75% for the 1989 to 1993 releases.

- The migration was characterized by very rapid downstream movement, with the majority of fish traveling the 280 km from Dexter to Willamette Falls in about 4 days; the number of smolts reaching Willamette Falls tailed off for up to a month after release.

- There was considerable among year variation in the poisson distribution of the outmigration pattern over the five years of this study.

- Smolt migration velocity was closely correlated with river velocity; individual fish did not always migrate at a constant speed.

- Feeding during the outmigration appears to be important to the fish.

- Very few fish released from Willamette Hatchery residualized, with the frequency varying among years.

- Transfer of Willamette Hatchery spring chinook to the release site at Pengra Ramp is stressful.

- Physiological smolt status is closely correlated with migratory behavior.

- Radio telemetry is a valid tool for studying migratory behavior of spring chinook salmon in large river systems.

INTRODUCTION

The objective of our research was to examine in detail the migration of juvenile spring chinook salmon (Oncorhynchus tshawytscha) in the Willamette River, Oregon (Figure 1). We wanted to determine characteristics of seaward migration of spring chinook smolts in relation to the oxygen supplementation practices at the Oregon Department of Fish and Wildlife (ODFW) Willamette Hatchery and use this information to strengthen the design of the oxygen supplementation project (Keefe et al., 1994).

There is little information available on the effects of oxygen supplementation at hatcheries on the migratory characteristics of juvenile salmon. Such information is required to assess the use of oxygen supplementation as a means of improving hatchery production, its effect on imprinting of juveniles, and finally the return of adults. In the event that oxygen supplementation provides for improved production and survival of juvenile chinook salmon at Willamette Hatchery, background information on the migration characteristics of these fish will be required to effectively utilize the increased production within the goals of the Willamette Fish Management Plan. Furthermore this technology may be instrumental in the goal of doubling the runs of spring chinook salmon in the Columbia River (NWPPC Columbia River Fish and Wildlife Program). While evaluation of success is dependent on evaluation of the return of adults with coded wire tags, examination of the migratory characteristics of hatchery smolts may prove to be equally informative. Through our research it is possible to determine the rate at which individuals from various oxygenation treatment groups leave the Willamette River system, a factor which may be strongly related to adult return rate. Furthermore, this information is available within weeks of the time of release, allowing management decisions to be made without having to wait three or four years for coded wire tag data. Finally, since our study focuses on the freshwater phase of the juvenile spring chinook life history, data collected will be independent of the year-to-year variability associated with oceanic conditions.

In addition to serving as a realistic means with which to assess oxygenation for upper Columbia River hatcheries, our study on Willamette Hatchery stock will provide background information required to effectively utilize increased production within the goals of the Willamette Fish Management Plan. Information that will be required includes: 1) the length of the latent period (if any) after release from the hatchery but before migration begins, 2) the migration rate through the river, 3) the extent of residualism (if any), 4) the physiological quality and feeding of migrants, and 5) the degree of predation to which migrants or residuals are exposed.

The overall approach w-as to initially gain a general understanding of outmigrant behavior exhibited by juvenile spring chinook salmon reared at Willamette Hatchery according to “traditional” rearing practices, before the

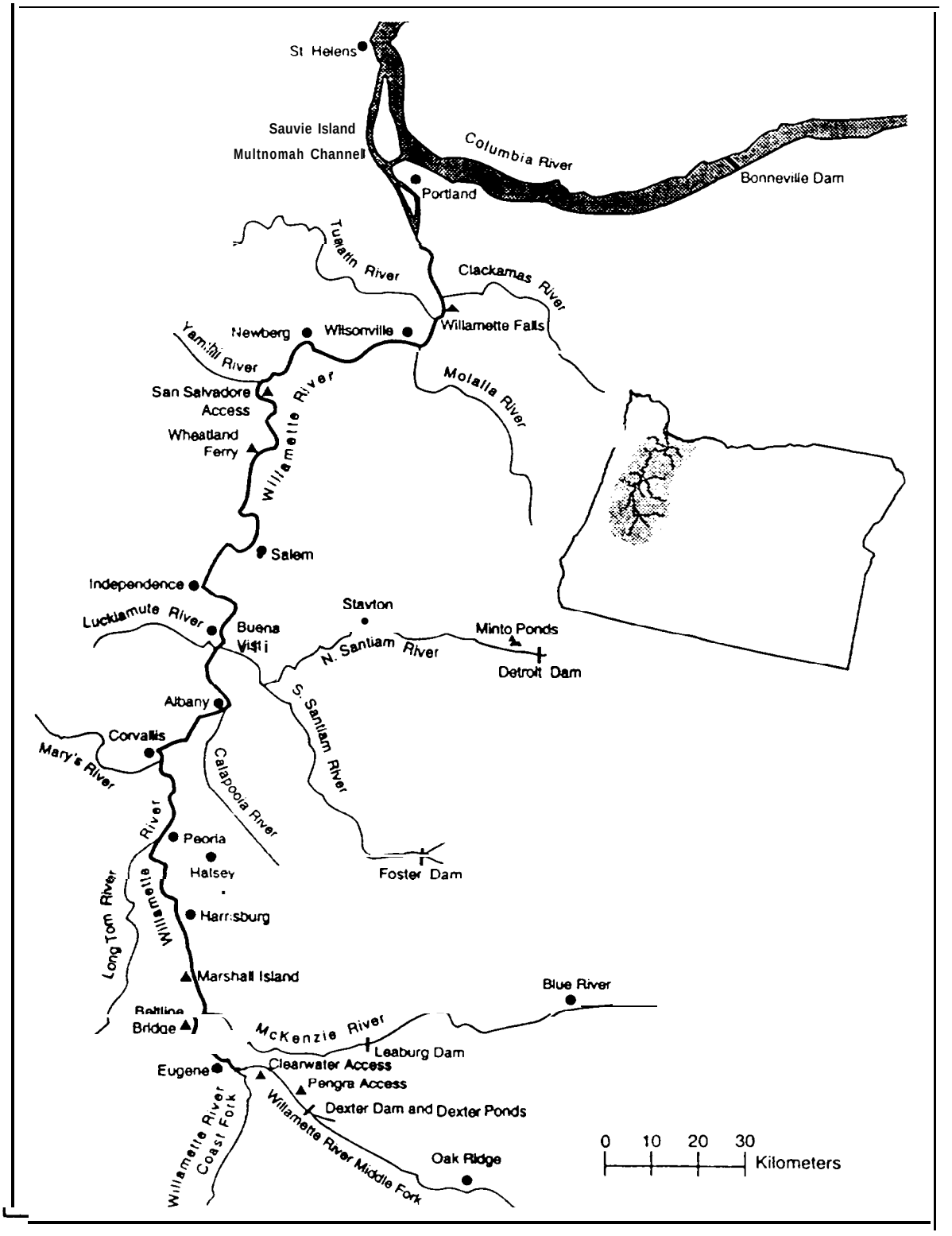


Figure 1. The Willamette River study area, showing the tributaries, dams, **cities,** and other **areas mentioned in the text.**

implementation of oxygen supplementation and experimental rearing regimes (see Bradford et al. 1989, 1990). We used the results obtained in 1989 and 1990 to formulate a tagging, collection, and sampling program for juveniles reared at Willamette Hatchery according to different treatments of rearing density and oxygen supplementation in 1991.

For 1992 and 1993 we repeated the research plan developed in 1991 incorporating use of the newly constructed Downstream Migrant Bypass System, at Portland General Electric's Sullivan Plant (West Linn), to sample large numbers of smolts at Willamette Falls.

METHODS

We studied Willamette stock spring chinook salmon raised at the ODFW Willamette Hatchery, Oak Ridge, Oregon from 1989 to 1993. Experiments in 1989 and 1990, were conducted on fish raised with standard hatchery practices (viz. $1 lb/ft^3$ at release, without oxygen supplementation). In 1991, ODFW implemented an oxygenation study which was designed to test the effects of oxygen supplementation, increased rearing density, and water recirculation (Michigan Series) on smolt growth and survival in the hatchery, and on return rates from the ocean.

Our primary objectives included: 1) evaluating the physiological responses of Willamette Hatchery smolts (control and experimental rearing regimes) to crowding, loading, truck transport, and release in the upper Willamette River below Dexter Dam, 2) characterizing the behavior of outmigrant juvenile spring chinook salmon reared according to control and experimental regimes at Willamette Hatchery, 3) recapturing outmigrant juveniles near Willamette Falls (after migrating about 280 km) and evaluating their physiological status, 4) surveying selected river sites (upper, middle, and lower Willamette River) for the presence of juvenile spring chinook salmon (possible "residual" non-migrants) over an extended time period following the release of smolts from Willamette Hatchery , and 5) evaluating the food habits (stomach contents) of all smolts collected from the river.

Physiological Response of Willamette Hatchery Juvenile Spring Chinook Salmon to Collection, Transportation, and Release: Evaluation of Plasma Cortisol and Na+/K+ gill ATPase Levels in Control and Experimental Treatments

We monitored the physiological responses of hatchery-reared spring chinook salmon smolts to the combined physical processes of crowding fish in the hatchery raceway, loading onto a transport truck, transporting to the liberation site, and release into the upper Willamette River below Dexter Dam (at Pengra Ramp, River KM 323). We measured plasma cortisol concentrations

before and after crowding and transport in order to assess the activitv of the hypothalamic-pituitary-interrenal axis (Donaldson, 1981) and thereby assess the degree of stress experienced by fish subjected to these handling procedures It is generally accepted that plasma cortisol levels provide a reliable index of the primary, or neuroendocrine, response to acute stress (Mazeaud et al., 1977). We also monitored cortisol to provide insight into the developmental stages of the fish, since cortisol concentration is dynamic during the process of smoltification (Barton et al., 1985).

For plasma cortisol determinations (1989-1993) all fish were quickly netted and placed immediately into a 40 1 bucket containing a lethal dose of MS-222 (tricaine-methanesulfonate, 200 mg/l) buffered with $NaHCO_3$ (500 mg/1). We bled individual fish by severing the caudal peduncle and collected blood in ammonium-heparinized capillary tubes. We separated plasma by centrifugation and temporarily stored it on dry ice, then at - 80 °C until time of assay We measured cortisol directly in 10 µl of plasma following the radioimmunoassay procedure of Foster and Dunn (1974), as modified by Redding et al. (1984)

We also assessed smoltification of the fish reared at Willamette Hatchery by measuring gill ATPase from 1990 to 1993. Changes in activity of gill Na+/ K+ ATPase, an enzyme indicative of smolting (Giles and Vanstone **1976),** was quantified by dissecting gill tissues (from three arches) from all of the pre-crowded fish described above, and placing these into I ml of gill enzyme buifer. Tissues in buffer were frozen on dry ice temporarily and then stored'at -80 °C. We analyzed these tissues for gill ATPase activity in the laboratory according to the method of Zaugg (1982). Except for 1992 (when analysis was conducted at OSU), these analyses were completed at the Sational Marine Fisheries Service (NMFS) laboratory, Columbia River Fishery Research Center, Cook, WA. In 1993 the assay was modified to support smaller tissue collections (tissue from part of just one gill arch) (Schrock et al., 1994). Extensive comparative testing in both laboratories assured uniformity of test procedures and results, allowing networking with the smolt quality monitoring study also funded by BPA.

In 1989 we netted 15 fish from raceway (pond) #6 (standard rearing practices) at approximately 1230 hours (prior to crowding) in order to obtain resting cortisol levels. At 1300 hours, hatcherv personnel crowded all fish to one end of the raceway, netted samples of 100-200 fish for pre-liberation weight determinations, and pumped fish from the raceway up into the transport truck. The truck departed Willamette Hatchery at 1405 hours and arrived at the liberation site (Pengra Access, River KM 323) at 1500 hours. At 1504 hours, we netted a second sample of 14 fish for cortisol determination as they were liberated into the Willamette River. Both groups of fish were bled as described above

In 1990 we collected a sample of 15 fish for cortisol and ATPase determination from the raceway (raceway #6 at Willamette Hatchery) on 12 March at approximately 1200 hours (prior to crowding). At 1325 hours, hatchery

personnel crowded all fish to one end of the raceway, netted samples of 100-200 fish for pre-liberation weight determinations, and pumped fish from the raceway up into the transport truck. This truck departed Willamette Hatchery at 1407 hours and arrived at Pengra Access at 1456 hours. At 1510 hours we sampled 15 fish, again for cortisol and ATPase determination, immediately as they were liberated from the truck into the Willamette River.

1991 was the first year in which smolts were released following production from the oxygen supplementation treatments at Willamette Hatchery. Accordingly, we expanded the scope of the study to include juvenile fish reared in control and experimental rearing regimes (treatments). The following treatment groups, which included the most extreme rearing regimes, were chosen for study (for each group the two ponds represent replicate treatments):

1) Ponds #7 and #17: Standard Ponds (Controls); fish reared under conditions of "standard" density (1 lb/ft^3 at release) without 02 supplementation; hereafter called "Standard".

2) Ponds #9 and #19: Triple Density Ponds; fish reared under conditions of three times standard density (3 lb/ft^3) with 02 supplementation to achieve saturation at exit; hereafter called "Triple Density ".

3) Ponds #10 (North and South): Third Series Michigan Ponds; fish reared in the third pass of the "Michigan Series" (water cycled from first and second Michigan ponds) under conditions of triple density with 02 supplementation; hereafter called "Third Michigan".

We collected blood samples from juvenile fish reared in ponds #7, #9, and #10 South; fish from the corresponding replicate ponds (#17, #19, and #10 North) were used in the radio telemetry study described below. Samples from 20 fish per pond were collected on 28 February between 0730 and 1000 hours (prior to crowding) in order to establish "resting" cortisol and existing ATPase levels. For each pond, in turn, hatchery personnel crowded fish to one end of the raceway, netted samples of 100-200 fish for pre-liberation weight determinations, and pumped fish from the raceway up into the transport trucks. A sampling crew at Pengra Access collected a second set of 20 blood samples per pond for cortisol determination as the fish were being liberated from the trucks into the Willamette River.

In 1992 we again collected blood and gill samples from juvenile fish reared in ponds #7, #9, and #10 North. On 1 March between 1700 and 2000 hours (prior to crowding) we collected blood and gills from 16 smolts reared under standard conditions in pond #7, and 20 smolts each from tripie density conditions (pond

#9) and third Michigan conditions (pond #10 North) in order to establish "resting" cortisol and existing ATPase levels. At 0730 hours on 2 March hatchery personnel began the transportation process and pumped fish from the raceway up into the transport trucks. Again we collected blood from fish (N = 20 fish per treatment) by netting them immediately as they were liberated from the trucks into the Willamette River at the Pengra Access release site.

Samples for 1993 were collected similarly to years prior with two exceptions. First we collected fish from only raceway #10 South of the third Michigan ponds; Pond #10 North (also third Michigan treatment) held fish with a high incidence of Bacterial Kidney Disease (BKD). Second, ODFW originally scheduled the release of fish from Willamette Hatchery for 2 March Owing to questions of potential effects of hatchery fish on Columbia River endangered chinook and sockeye (Oncorhynchus nerka) stocks, the Endangered Species Act (ESA) permit required by the National Marine Fisheries Service (NMFS) was not issued until two weeks later. Pre-Loading blood and gill samples were obtained in the late afternoon of 12 March. We obtained samples at release in the morning of 15 March.

Radio-Tracking Outmigrant Juvenile Spring Chinook Salmon

When our study began in 1989 we planned to determine outmigration timing from fish captured **at a** downstream migrant trap under construction by Portland General Electric at the T.W. Sullivan Plant, West Linn. In fact, this trap was not in operation until November 1991.

As a result we settled on radio-telemetry as an attractive alternative for tracking the downstream movements of smolts. Our study employed two transmitter designs, two receiver designs and two frequency ranges.

Transmitters. Transmitters were designed to operate at 60 pulses per second, and each was separated by 10-20 KHz so all 60 individual fish could be unambiguously identified using a scan time of 4 sec. In 1989, 1990 and 1991 our transmitters were manufactured by Advanced Telemetry, Inc (Isanti, MN). The frequency range was 48-50 MHz. In 1989 we used a trial group of tags whose battery life was 3 days (calculated at 80% of maximum), weighing 1.5-1.8 g in air; a later group of tags, with battery life of 10 days, weighed 2.0-2.3 g in air; each had an antenna 30 cm long. In 1990 and 1991, the average weight of tags was 2.2 g in air (1.2 g in water); each had a 30 cm antenna; and battery life was 14 days. In 1992 we ordered tags from Lotek Engineering (Ontario, Canada). These weighed 3.0 g in water (3.2 g in air), and had an 18 day battery liie. In 1993 we changed to a higher frequency (148-150 MHz) and again ordered tags from ATS; these weighed 1.9 g in air, with a battery life of 14 days.

Receivers. We used two types of radio telemetry receivers. The ATS receiver (Challenger Model 2000) was used in boats and in manual tracking from shore. From 1989 through 1992, with the 48-50 MHz frequency, we used a hand-held loop antenna supplied by ATS; in 1993 with higher frequencies of 148-150 MHz we used a four element yagi receiving antenna (Cushcraft Mfg., NH). From 1991 through 1993 we also used digital recording data loggers (Lotek Engineering, Model SRX_400, Configuration 3) connected to a yagi antenna for the unattended collection of telemetry data at several sites along the river. Successful operation of these receivers depended on careful programming specific to the transmitter and location, as well as careful treatment of the data following collection. For most data logging applications programming was as follows: signal boundaries (limits of signal pulse in milliseconds) 400 to 650; continuous record time out 5 records; windows in bpm, fast 1, medium 40-80, slow 1; global noise threshold 10, noise blank level 30. In 1993 we learned that noise could be most easily separated from real data but analyzing records sorted by beats per minute, as well as comparing all records along the river for each fish to spot anomalies.

1989. We planned to release 15-20 smolts reared at and released from Dexter Pond (an ODFW rearing facility just below Dexter Dam) directly into the Willamette River at RKM 327. Our radios did not arrive in time, however, so approximately 100 smolts were transferred from their home raceway to a 1700 l holding tank equipped with flowing river water on 6 March. On 8 March, five fish greater than 16 cm fork length (smaller fish were rejected to insure that the weight of transmitters was no more than 2% of fish weight, to minimize buoyancy problems), were anaesthetized (MS 222, 50 mg/l buffered with NaHC03, 100 mg/liter) and implanted (tagged) with radios having a battery life of three days, following the protocol of Ward and Miller (1988); transmitters were inserted into the stomach using a plastic pipette as a trochar. In order to monitor recovery from the tagging procedure and check for tag retention, tagged fish were sequestered in a perforated 120 1 tank, suspended in the larger tank. Twenty four hours later we discovered that one fish had regurgitated its transmitter; when this same fish rejected a second implant, we selected and tagged a replacement fish. At noon on 9 March, all fish in the holding tank were captured by net and transferred to a clean 120 1 transport tank, boated to the middle of the river at Dexter, and were released at 1251 hours. We followed these fish as far downstream as the confluence of the McKenzie and Willamette Rivers (RKM 287).

On 14 April we selected 15 smolts (61.0-116.8 g wet) from the Willamette Hatchery April time-release group, and tagged them with transmitters scheduled to operate for 10 days. These fish were sequestered in a 120 1 perforated tank in their home raceway until 16 April, when we liberated them into the home raceway. All fish in the raceway were transported to the Pengra Access on 17 April and released by ODFW. We followed these fish as far downstream as possible.

1990. We anaesthetized 34 juvenile spring chinook smolts on 9 March (48.6-71.0 g wet weight; Willamette Hatchery 1989 brood year) and tagged them with radio transmitters having batteries designed to provide 14 days of power. They were then temporarily sequestered in perforated 120 l tanks (17 fish per tank) suspended in the home raceway until 11 March at which time we quietly liberated them into the raceway (containing approximately 20,000 fish). On 12 March, 31 unique radio signals could be detected in the vicinity of the raceway, when all fish were transported by ODFW to Pengra Access and released.

The tracking "strategy" we adopted in 1990 was to monitor the downstream progress of a majority of the 31 tagged fish, while staying in front of the fastest fish. Initially, a tracking crew remained at the liberation site and documented the behavior of released fish by noting the times at which individuals departed the immediate vicinity and began to move downstream. After these moving fish had left the liberation site, this crew proceeded downstream to the first of eight pre-established, fixed riverbank tracking stations. These stations were established at Clearwater boat ramp (Jasper, RKM 307), Beltline Bridge (Eugene, RKM 287), Marshall Island (Coberg, RKM 272), Willamette Park (Corvallis, RKM 216), Buena Vista (RKM 171), Independence (RKM 154), San Salvadore Park (Saint Paul, RKM 92), and Bernert Landing (just above Willamette Falls at RKM 45).

In addition to these fixed riverbank tracking stations, boats were employed, where appropriate, to locate individual fish in the lower river. An unattended data-logger and yagi antenna (ATS Model 5040) recording station was also established on the riverbank at Oregon City Marina (just above Willamette Falls; RKM 43). Finally, we were assisted in our efforts to track juveniles in the lower Willamette River (i.e., below Willamette Falls and in the vicinity of Portland) by Dave Ward (ODFW, Clackamas Research Laboratory), who was simultaneously conducting a radio telemetry study of spring chinook outmigration through the Port of Portland area.

1991. On 26 February 1991, 20 fish each from ponds #17 (standard density), #19 (triple density), and #10 North (third Michigan) were netted, anesthetized (MS-222, 50 mg/liter buffered with $NaHCO_3$, 100 mg/l) and tagged with stomach implant transmitters equipped with batteries designed to power them for 14 days. Again, fish shorter than 17 cm fork length were rejected; this insured that the weight of radio transmitters (1.2 g in water) represented no more than 2% of the total fish wet weight. As fish reared in the experimental ponds were, on the **average,** smaller than fish reared in standard ponds (Joe Sheehan, ODFW, pers. comm.), fish used in the radio telemetry study were biased towards the high end of size-frequency distributions. The average length of all radio-tagged fish was 18.2 cm; average sizes of tagged fish did not differ significantly among ponds representing different treatments.

In order to monitor recovery from the tagging procedure and check for tag retention, all tagged fish were temporarily sequestered in perforated 120 1 tanks suspended in pond #I6 (one-half standard density without supplemental O_2) until 28 February, at which time they were quietly liberated into this raceway. Pond # 16 was chosen for temporary holding to insure that all radio-tagged fish could be loaded onto the same liberation truck and released together. On 1 March, we could detect 59 of 60 radio signals in the raceway. On this date, all fish were transported by truck to Pengra Access and released. The tracking strategy followed that of the previous year, except that there was no crew from ODFW to track fish in the lower river.

1992. In 1992, we released two groups of smolts to learn more about outmigration under different environmental conditions. On 28 February 1992, we netted 10 fish each from ponds #17 (standard density) and #10 South (third Michigan), and nine fish from pond #19 (triple density); we anesthetized, weighed and measured each fish, and inserted transmitters into their stomachs. During this procedure we rejected fish shorter than 17 cm fork length. Again, fish reared in the experimental ponds were on average, smaller than fish reared in standard ponds. Consequently our fish were biased toward the high end of size-frequency distributions. The average length of all radio-tagged fish was 19.0 cm and average weight was 79.0 g; average sizes of tagged fish did not differ significantly among ponds representing different treatments.

All tagged fish were again temporarily sequestered in perforated 120 1 tanks suspended in pond #16 (one-half standard density without supplemental O_2); pond #16 was again chosen for temporary holding to insure that all radio-tagged fish would be loaded onto the same liberation truck and released together. When we checked radio performance at 1000 hours on 29 February, two transmitters from fish of the third Michigan treatment had malfunctioned as did one in a fish from the standard pond. Another check at 1600 hours on 1 March showed that three additional transmitters had failed, in fish from each treatment. At this time we quietly liberated all fish into the raceway of pond #16. On 2 March all fish were transported by truck to Pengra Access and released at 1020 hours. An immediate check of all frequencies showed that 10 transmitters were not functioning; apparently some of these operated sporadically and some were transmitting continuously. We called the manufacturer, and were told that their potting material had failed and the transmitters were absorbing water, causing irregular pulses. We had previously tested these tags for 12 hours in water, as is our standard procedure with adult and juvenile aquatic tags.

The tracking strategy we adopted was to monitor the downstream progress of a majority of tagged fish, and if possible stay in front of the fastest fish. We also followed some individual fish throughout portions of their outmigration. Initially, a tracking crew remained at the liberation site and documented the behavior of released fish by noting the times at which individuals departed the

immediate vicinity and began to move downstream out of range. We located fish by monitoring the scanning, programmable ATS receiver into which all 29 radio frequencies had been stored in memory. A second crew immediately began tracking fish from a drift boat in the area between Pengra and Jasper (RKM 314). They used the same electronic equipment.

A third crew put into operation the first of five remote data loggers at Mahogany Lane (RKM 309, near Clearwater Access); we positioned others at the following locations as the lead fish approached the area: Log House (RKM 274, near Marshall Island Access), Peoria (RKM 227), Wheatland Ferry (RKM 278), Yorks (Rock Island, RKM 49). These consisted of a yagi antenna oriented about 45" upstream, a LOTEK receiver (model SRX_400), and 12 v automobile battery; all but the antenna were bundled in a locked, waterproof container. We also used an ATS receiver at the Sullivan Plant (RKM 43) to monitor fish in the area of Willamette Falls; both PGE sampling personnel (see below) and our crews monitored this receiver when possible.

In addition to these fixed riverbank tracking stations and the drift boat in the upper river, we used a jet boat to locate and follow individual fish in the lower river.

With the crews in boats and the remote data loggers, we monitored the downstream progress of outmigrants 24 h each day. An effort was made to follow as many of the tagged fish as far downstream as Willamette Falls. Because of the uncertainty associated with radio failure, we also hired a fixed wing airplane to find fish on 7 March. The loop antenna was affixed to a wing strut. Flying at altitudes of from 700 to 2,000 ft. above ground level at speeds of 75 knots allowed effective scanning of about 30 frequencies. We were successful in locating several fish in the area of Newberg and directed boats to their locations.

Marking and tracking the second group of juveniles was similar to the first. On 2 March we randomly netted 100 fish each from ponds #17, #19, and #10 South and sequestered them separately in 1 X 1 X 5 m flow through troughs inside the Willamette Hatchery salmon building. Hatchery personnel fed these fish daily until 20 March, when we returned to implant radios in 10 fish from each treatment group, and release them into the appropriate tank. We attempted to select fish larger than 17 cm fork length, but noted that smolts from the truiple density and third Michigan treatment groups were generally too small; we implanted a transmitter in only one smolt from triple density ponds greater than 17 cm, and one smolt from third Michigan ponds was smaller than 17 cm. Bv 21 March five fish from the triple density group and one from the third Michigan had died, and an additional smolt from the triple density group was dying We returned to the hatchery and implanted the seven radios from dead smolts in seven fish from the standard treatment greater than 17 cm; these exhibited recovery behavior more normal then their smaller counterparts.

By 24 March one additional fish from third the Michigan treatment had died, and we did not re-implant this radio. At 0845 hours on this day we released 29 smolts (17 standard, 4 triple density, and 8 third -Michigan) at Pengra after transit in a 400 1 tank equipped with oxygen. Tracking proceeded similarly to the first release. With the reduced river flow at this time, fish outmigration had slowed and we were able to stop the boats and observe individuals more easily.

1993. We anaesthetized and tagged smolts at Willamette Hatchery in the afternoon of 12 March. There were 19 fish from Standard pond #17, 18 fish from Triple density pond #19, and 18 fish from Third Michigan pond #10 south. They were then sequestered in three perforated tanks suspended in raceway #16. We tagged an additional 10 fish from the Standard raceway, and transported them to Pengra **Access** in 120 1 tanks supplied with oxygen, along with 26 untagged smolts. One fish regurgitated its tag during the 45 min transport, so we placed this tag in another fish. All fish were then transferred to **a** perforated sequestering tank inside a 3.3 m^3 covered net pen. On 14 March we released the fish into the net pen proper; all transmitters were functioning. Later at the hatchery we released the radio-tagged fish there into raceway #16; there were no tag regurgitations and all fish seemed healthy.

In the morning of 15 March, hatchery fish were loaded and trucked to Pengra Access, as in previous years. When the truck transporting our marked fish released its load, our boat and crew were at the net pen and simultaneously released the fish there. Our tracking strategy was similar to previous years. We listened for fish to leave the Pengra area both manually and with the data loggers; this proved very useful because it allowed a check of transmitter beats per minute (BPM), which we later used to sort noise from real events at other logger sites. A crew in a drift boat followed fish as far **as** Eugene (RKM 298) that night; thereafter we used a jet boat. We also established fixed data logging sites as follows: Mahogany Lane (between Pengra and Clearwater Access), mouth of the McKenzie River, Marshall Island, Peoria (not used), Corvallis, Buena Vista (flood event destroyed the data here), Wheatland Ferry, Newberg, Rock Island/Coalca, and Willamette Falls.

Estimation of Willamette River Velocity

For 1991, 1992, and 1993 we estimated Willamette River velocity at the locations where we monitored the passage of fish. We measured the river velocity at 60% of the river depth, using a Marsh-McBirney flow meter attached to a fiberglass pole. Three measurements, the first at one third, the second at one half and the third at three quarters the width of the river were averaged to estimate flow velocity at each location.

Recaprure of Outmigrant Juvenile Spring Chinook Salmon Above Willamette **Falls**

Until installation of a downstream migrant trap at Willamette Falls in the fall of 1991, we sought a means of capturing large numbers of smolts to help evaluate our telemetry and physiological data. We tried Humphry traps and fyke nets without success. Finally we were successful with beach seines (106.7 meters long x 2.4 meters deep), especially at Peach Cove (RKM 51).

1990. We employed beach seines exclusively in the vicinity of Peach Cove to sample for the presence of outmigrant juvenile spring chinook salmon during March. The target group of fish in this case was the majority of the 1989 brood year production released from Willamette Hatchery; these fish (total N > 800,000) were transported by ODFW to Dexter Pond in late Februarv and held until 7 March, at which time they were released directly into the Willamette River (only Pond #6 at Willamette Hatchery, containing radio-tagged animals, was transported to Pengra Access point and released on 12 March). We assumed that the fastest fish from this release group would reach Peach Cove no sooner than day three after release. Accordingly, beach seining activities were initiated on 10 March, and were carried out at approximately three day intervals until 30 March with five sets made on each of seven sampling dates. The total numbers of fish taken were recorded, and where large numbers (> 10) of juvenile chinook salmon were found, gill tissues were sampled (as described above! and preserved for subsequent determination of ATPase activity.

1991. We again used beach seines in the vicinity of Peach Cove to sample for the presence of outmigrant juvenile spring chinook salmon during March The target group of fish was the majority of the 1990 brood year production from Willamette Hatchery, which were released into the upper Willamette River on 28 February. The last release of fish, including those with radio tags, was one day later, on 1 March. Beach seining activities were conducted on 8, 15 and 22 March. On each of three dates five sets were made. The total numbers of fish taken were recorded, and where large numbers (> 10) of juvenile spring chinook salmon were seined, gill tissues were sampled (as described above) and preserved for subsequent analysis of gill ATPase activity.

1992. A permanent trap was made available by Portland General Electric at Willamette Falls as an addition to the Downstream Migrant Bypass System at the T.W. Sullivan hydroelectric generator. The trap consisted of a holding area for fish screened from the turbine, a dewatering grate, and holding tanks below. Our target group of fish was the majority of the brood year 1991 production from Willamette Hatchery, including those with radio tags, which were released into the upper Willamette River. PGE estimated that 80% of smolts which reach the Sullivan forebay are diverted into the screened channel around turbine number 13 and into the trap. The percent of fish which enter the forebay depends on

river conditions; PGE takes about 5,000 cfs, which is between 10 and 95 % of river flow depending on total flow.

We began sampling fish at the trap on 5 March 1992 when, based on previous years' telemetry data, we expected the first smolts from Willamette Hatchery to reach the Falls. We sampled for eleven 24 h periods through 9 April, at first, every other day, then every third day, and finally once a week. Sampling consisted of collecting seven adipose clipped smolts every three hours, during the 24 h period; these fish had coded wire tags in their heads identifying their origin and treatment. During the initial collections when few smolts passed through the trap, we collected for 30 minutes using two dip nets to block the aperture between the raceway and dewatering rack. Later when the numbers of smolts increased, we simply dip-netted them from the raceway. We placed all smolts into anesthetic, then quickly sorted to release unmarked fish; the remaining fish were allowed to die in the MS 222. We measured and weighed the fish we collected, extracted blood for cortisol, and gill tissues for ATPase determination. The fish heads were presented to the ODFW laboratory at Clackamas for determination of hatchery origin and treatment by CWT analysis. We froze the bodies for later stomach analysis.

To provide for a pre-screening sample to assess stress we also sampled several dozen smolts by dip netting them from just upstream of the turbine #13 diversion screen in late March and early April.

1993. Our sampling procedures were similar to those in 1992. But owing to exceptionally high river flows, and our work schedule tracking radio-tagged fish, we did not begin the first of 10 24 h sampling periods until 19 March. Based on our telemetry data this was after the first Willamette Hatchery smolts passed the Falls. Additional 24 h sampling periods were conducted on 21, 23,25,27,29, and 31 March, and 2, 4, and 6, April. The high flows prevented successful dip-netting of fish from in front of turbine #13. In fact, water levels were so high that PGE recognized fish were not being effectively guided into the last, screened turbine. We preserved guts from each fish in 10% formalin for food analysis (described below).

Evaluation of Juvenile Spring Chinook "Residualism" and Food Habits

We evaluated the possibility that significant numbers of hatchery-reared juvenile spring chinook might demonstrate a tendency toward non-migrant behavior, or "residualism" in fresh water, following release. In 1990 selected Willamette River sites were surveyed for the presence of juvenile chinook beginning in late March, and extending through mid-June. Most of the survey work was carried out by electrofishing from a shock-boat; on several occasions hook-and-line methods were employed to sample for fish.

In general, sites were chosen in the upper, middle, and lower river close enough to boat launches to support the electroshock boat. Surveys in the upper river were concentrated in the immediate vicinity of the Willamette Hatchery 1989 brood year release sites (Dexter Dam and Pengra Access); surveys of the lower river focused on the region just above Willamette Falls, at the mouth of the Tualitan River. Various sites were chosen to represent the "middle" river (see results for specific locations).

In addition to recording numbers of juvenile chinook salmon taken at a given site on **a** particular date, gill tissues were sampled for subsequent analysis of gill ATPase activity, and carcasses were preserved in 10% formalin for subsequent analysis of gut contents. After carcasses were adequately "fixed" in formalin, they were transferred to 40% isopropanol. Gut contents were collected into scintillation vials, and total volumes were estimated by comparing the settled vial contents with a calibrated "standard" vial. Finally, a qualitative analysis of gut contents was carried out by viewing vial contents at low power magnification under a dissecting microscope.

In 1991,1992 and 1993 selected sites in the upper, middle, and lower Willamette River were surveyed by electroshocking for the presence of juvenile spring chinook. In 1991 we sampled from mid-March through mid-April; in 1992 from mid-March to early May, and in 1993 during April only. Surveys in the "upper" river concentrated in the vicinity of where the Willamette Hatchery fish were released; surveys of the "middle" river were conducted between the Buena Vista boat ramp and the upstream end of Wells Island (RKM 171), around Kiger Island (RKM 217), and near Peoria (Sam Dawes/Buckskin Mary Landings, RKM 235); surveys of the "lower" river focused on the region just above Willamette Falls, at the mouth of the Tualitan River near Bernert Landing and in the sloughs behind Rock Island (RKM 48).

RESULTS

Physical Characteristics of Fish Studied.

Our study of juveniles was limited to production from Willamette Hatchery. We took fish without respect to size for physiological samples. We were highly selective of size when selecting fish for radio tagging and attempted to see that the tag was no more than 2% of the fishes' weight. Table 1 shows that while our samples of fish reared in third Michigan ponds were generally smaller than others, our fish were generally the same size and therefore size would not be a significant variable in our results.

Table 1. Length and weight of juvenile spring chinook salmon sampled or radio-tagged at Willamette Hatchery, 1989-1993

YEAR/TREATMENT	REARING CONDITION	FORK LENGTH (CM)	WEIGHT (G)	NUMBER
1989				
TELEMETRY 1	STANDARD	<16		5
TELEMETRY 2	STANDARD	19.0 (0.34)	79.3 (3.74)	15
PRE-LOADING		15.3 (0.47)	39.3 (4.49)	15
POST-TRANSPORT		15.5 (.39)		14
1990				
TELEMETRY	STANDARD	17.7 (0.09)	57.8 (1.02)	34
PRE-LOADING		13.7 (0.43)	27.5 (3.03)	17
POST-TRANSPORT		15.5 (0.43)		15
1991				
TELEMETRY	STANDARD	18.4 (0.17)	66.7 (2.42)	20
	TRIPLE DENSITY	18.1 (0.16)	64.2 (2.17)	20
	THIRD MICHIGAN	18.0 (0.15)	58.8 (1.66)	20
PRE-LOADING				
	STANDARD	15.8 (0.50)		20
	TRIPLE DINSITY	13.6 (0.44)		20
	THIRD MICHIGAN	14.5 (0.61)		20
POST-TRANSPORT				
	NORMAL DENSITY	16.3 (0.67)		20
	TRIPLE DENSITY	14.4 (0.43)		20
	THIRD MICHIGAN	13.8 (0.49)		20

YEAR/TREATMENT	REARING CONDITION	FORK LENGTH (CM)	WEIGHT (G)	NUMBER
1992				
TELEMETRY 1	STANDARD	9.1 (0.42)	81.3 (5.91)	10
	TRIPLE DENSITY	8.8 (0.44)	75.1 (5.38)	9
	THIRD MICHIGAN	9.1 (0.30)	80.1 (3.77)	10
TELEMETRY 2	STANDARD	8.6 (0.18)		17
	TRIPLE DENSITY	16.3 (0.3)		4
	THIRD MICHIGAN	8.9 (0.35)		9
PRE-LOADING	NORMAL DENSITY	16.5 (0.35)	48.8 (3.01)	16
	TRIPLE DENSITY	15.2 (0.32)	37.2 (2.80)	20
	THIRD MICHIGAN	14.6 (0.30)	34.5 (3.87)	20
POST-TRANSPORT	NORMAL DENSITY	16.2 (0.49)		20
	TRIPLE DENSITY	15.7 (0.54)		20
	THIRD MICHIGAN	16.3 (0.50)		20
1993				
TELEMETRY	STANDARD	18.7	74	19
	TRIPLE DENSITY	18.5	68.6	18
	THIRD MICHIGAN	19.6	83.4	18
	STANDARD (NET PEN)	18.4	68.7	10
PRE-LOADING	NORMAL DENSITY	15.6 (0.82)	47.5 (7.05)	20
	TRIPLE DENSITY	16.3 (0.57)	48.7 (4.80)	20
	THIRD MICHIGAN	16.4 (0.55)	48.4 (5.02)	20
POST-TRANSPORT	NORMAL DENSITY	15.3 (0.56)		20
	TRIPLE DENSITY	17.8 (0.49)		20
	THIRD MICHIGAN	16.0 (0.53)		20

Physiological Response of Willamette Hatchery Smolts to Collection and Transportation: Evaluation of Plasma Cortisol and Plasma Glucose Concentrations

The results of plasma cortisol determinations for smolts before and after truck transport prior to liberation in the Willamette River are found in Figures 2-6. For 1989 and 1990, when smolts had been reared under standard hatchery practices, pre-liberation values ranged from 9.9 ng/ml (1989) to 26.5 ng/ml (1990). At liberation, values ranged from 123.1 to 140.0 ng/ml, and were significantly elevated (p> .05) (Figures 2 and 3). In 1990 plasma glucose levels tended to be slightly higher in fish post-transport than in fish in the hatchery (89.9 $\pm$ 5.1 vs. 73.2 $\pm$ 5.5 mg/100 dl) (means and standard errors), however this difference was not statistically significant.

For 1991, 1992 and 1993 we have pre- and post-liberation cortisol values for smolts reared in standard ponds, triple density ponds, and third Michigan ponds. In 1991 cortisol levels in fish sampled at Willamette Hatchery before crowding and transport (resting levels) were significantly higher ($p < 0.05$) in fish reared under conditions of standard density (19.0 $\pm$ 5.0 ng/ml) than in fish reared under conditions of the third pass of the Michigan Series (6.2 $\pm$ 1.3 ng/ml) (Figure 4). Resting cortisol levels in fish reared in triple density ponds tended to be intermediate between the other two treatment groups (11.6 $\pm$ 2.8 ng/ml), but were not statistically different from either. In all three treatment groups, cortisol levels in fish subjected to normal handling and liberation procedures were significantly elevated post-transport, compared with resting levels. Post-transport cortisol levels were higher ($p < 0.05$) in fish from the standard pond (126.7 $\pm$ 9.0 ng/ml) than from the triple density pond (103.1 $\pm$ 6.3 ng/ml) and the third Michigan pond (92.7 $\pm$ 7.9 ng/ml). Post- transport cortisol levels in fish from the latter treatment groups did not differ significantly (Figure 4).

For 1992 resting cortisol levels in fish sampled before crowding, collection, and release were not significantly different ($p < 0.05$) in fish reared under standard conditions (26.9 $\pm$ 15.2 ng/ml), in fish from conditions of triple density (8.8 $\pm$ 1.83 ng/ml), or in fish reared in the third pass of the Michigan series (13.5 $\pm$ 3.7 ng/ml) (Figure 5). The average resting cortisol level in fish from standard density ponds was nearly twice as high as the other treatments, partly the result of one high outlying value. In all three treatment groups, cortisol levels in fish subjected to normal handling and liberation procedures were significantly elevated (six times resting) post-transport, compared with resting levels, but were not significantly different from each other; standard 120.9 $\pm$ 5.6 ng/ml, triple density 107.0 $\pm$ 5.8, and third Michigan 121.5 $\pm$ 9.9 ng/ml.

In 1993 resting cortisol levels in fish from the standard treatment (12.6 $\pm$ 3.06 ng/ml) were significantly lower than either fish from triple density or third Michigan treatments (53.4 $\pm$ 7.19 and 36.7 $\pm$ 8.02 ng/ml, respectively) (Figure 6). Cortisol from fish at liberation was again significantly elevated above pre-

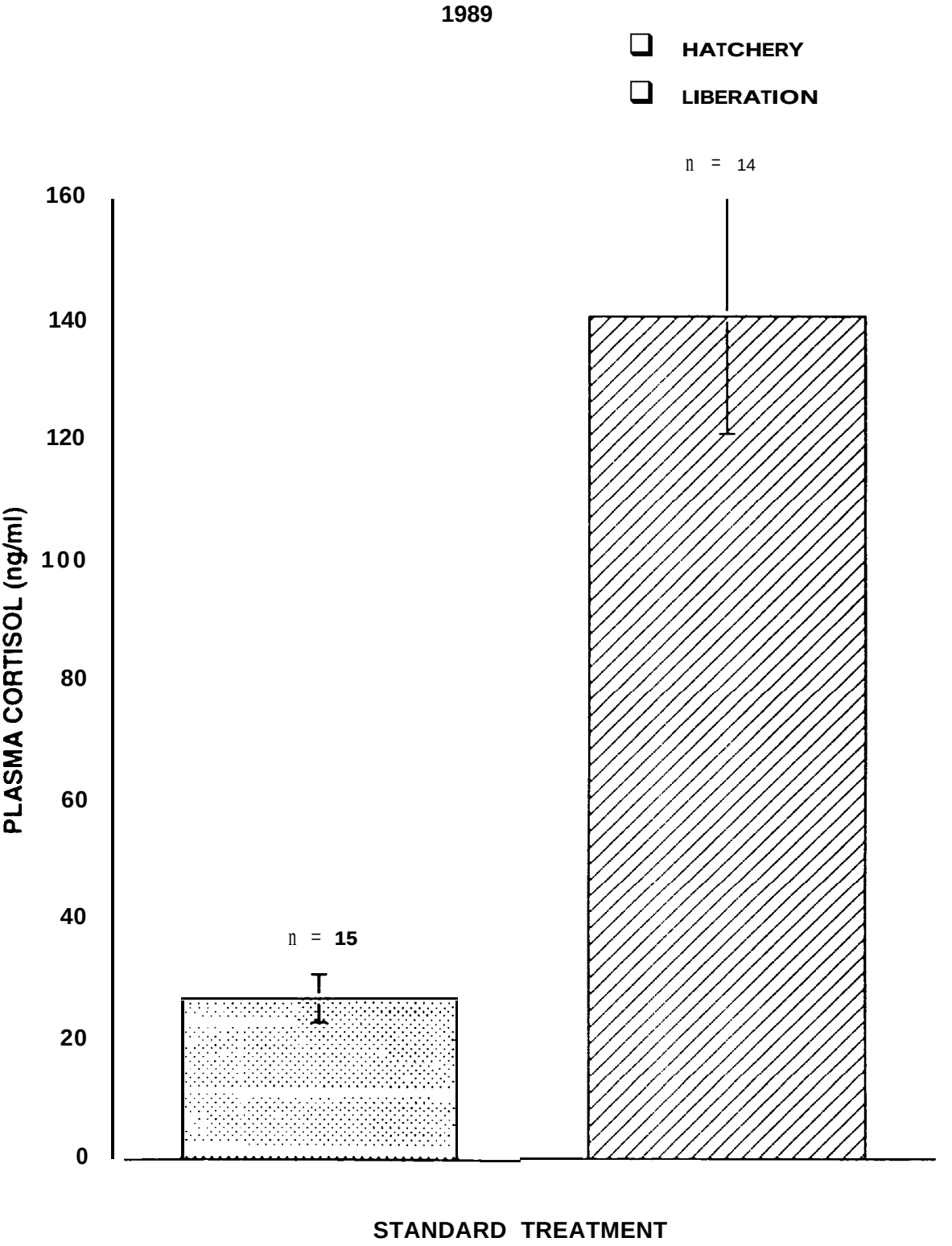


Figure 2. Plasma cortisol levels in juvenile spring chinook salmon (Willamette Hatchery, 1988 brood-year) before (Hatchery) and after (Liberation) release at Pengra Ramp (Willamette RKM 323) on 17 April 1989 Bars indicate the mean +SE. Bars labeled with different letters are statistically different ($p < 0.05$).

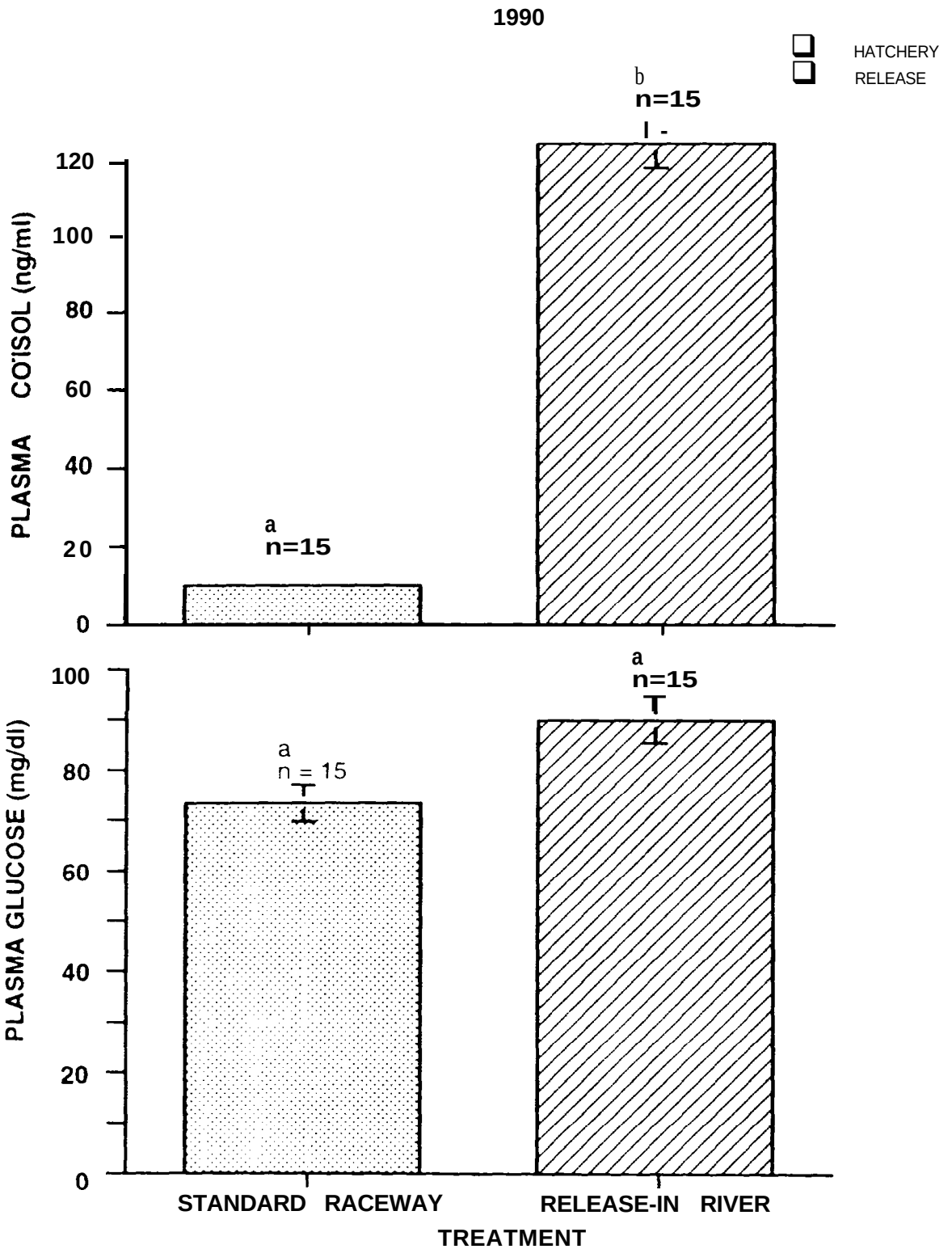


Figure 3. Plasma corisol and glucose levels in juvenile spring chinook salmon (Willamette l Hatchery I989 brood-year) before (Standard Raceway) and after (Release in River) release at Pengra Ramp (Willamette RKM 323) on 12 March 1990. Bars indicate the mean +SE. Bars labeled with different letters are statistically different ($p < 0.05$).

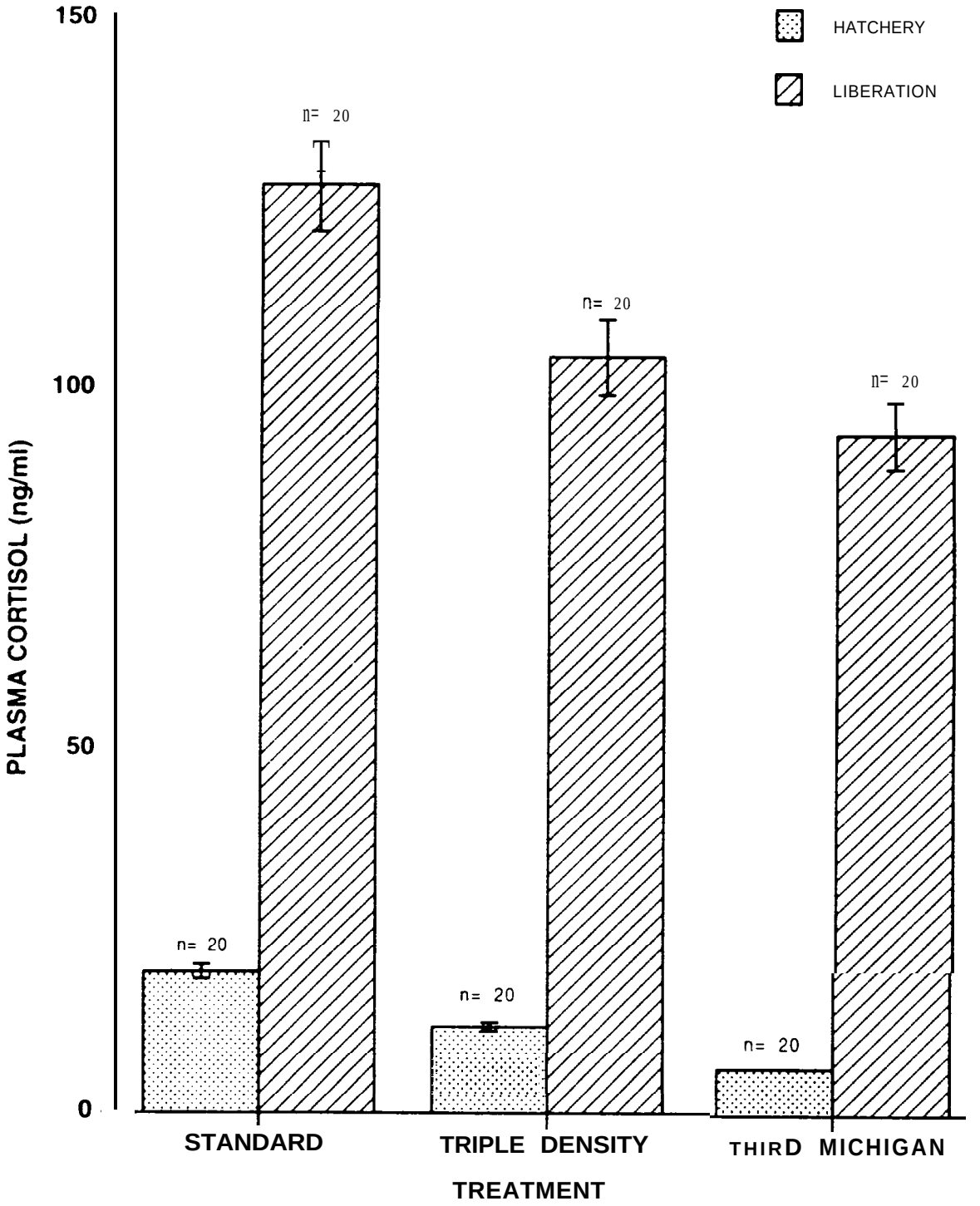


Figure 4. Plasma cortisol levels in juvenile spring chinook salmon from three treatments (Willamette Hatchery. 1990 brood-year) before (Hatchery) and after (Liberation) release at Pengra Ramp (Willamette RKM 323) on 28 February 1991 Bars indicate the mean +SE. Bars labeled with different letters are statistically different ($p < 0.05$).

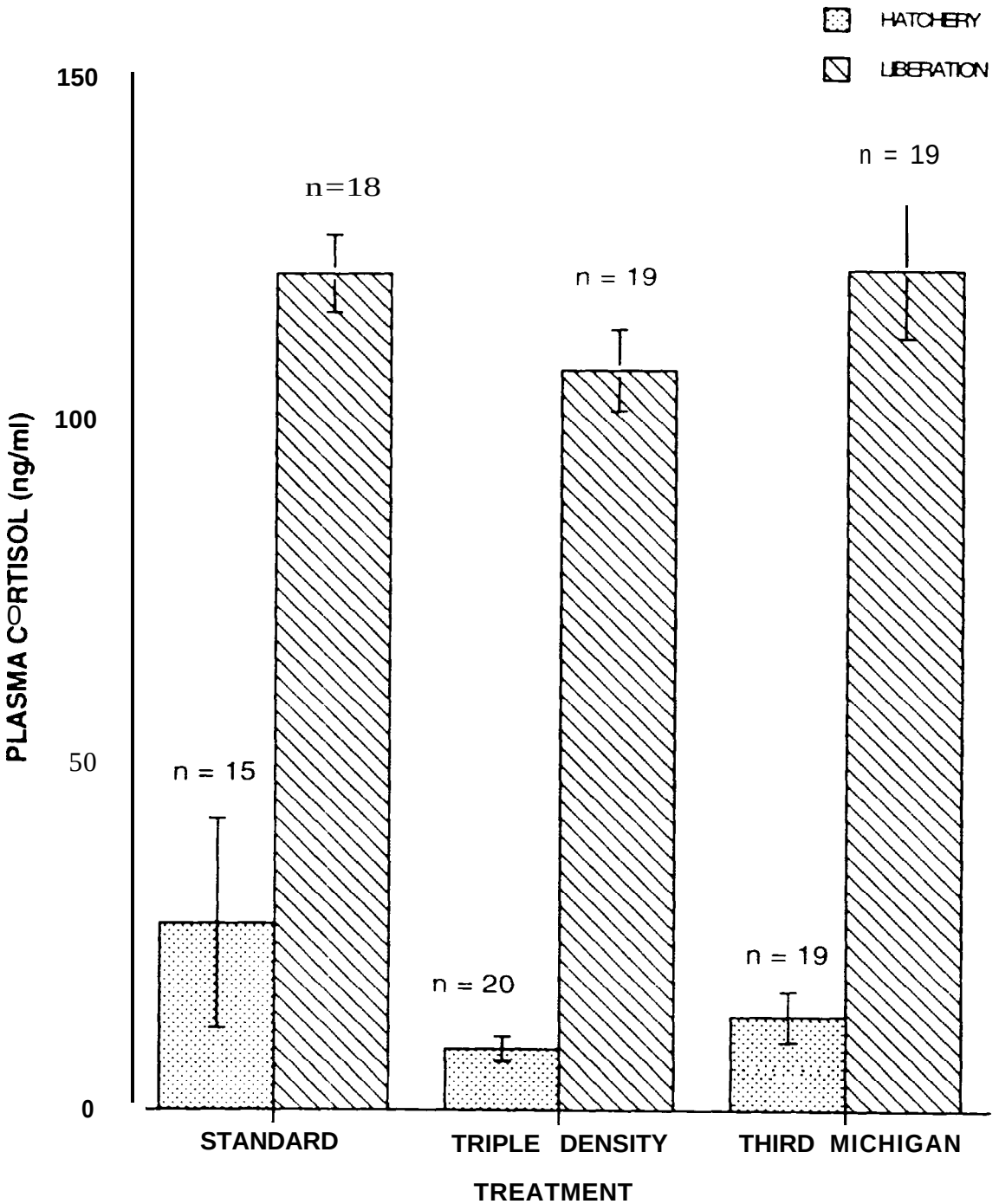


Figure 5. Plasma cortisol levels in juvenile spring chinook salmon (Willamette Hatchery. 1991 brood-year before (Hatchery) and after (Liberation) release at Pengra Ramp (Willamette RKM 323) on 2 March 1992. Bars Indicate the mean +SE. Bars labeled with different letters are statistically different ($p < 0.05$).

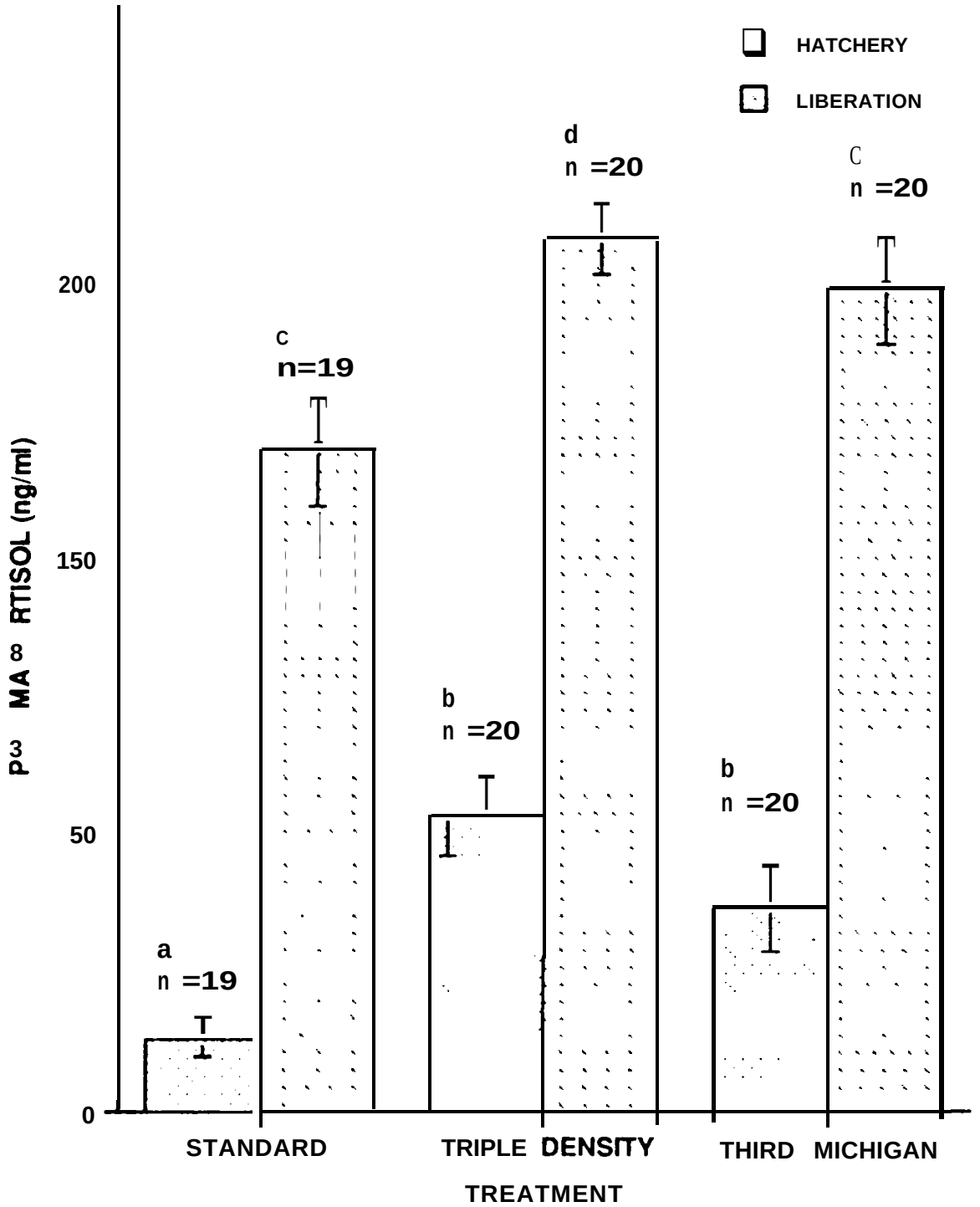


Figure 6. Plasma cortisol levels in juvenile spring chinook salmon (Willamette Hatchery, 1992 brood-year) before (Hatchery) and after (Liberation) release at Pengra Ramp (Willamett RKM 323) on 15 March 1993. Bars indicate the mean +SE. Bars labeled with different letters are statistically different ($p < 0.05$).

liberation levels. The third Michigan fish had mean levels of 148.9 ± 10.2 ng/ml, and fish from the triple density treatment had cortisol levels significantly greater than those from the standard treatment (158.1 ± 6.53 and 119.6 ± 10.23 ng/ml, respectively).

Movement Characteristics of Outmigrant Smolts

1989. The five radio-tagged smolts in the 1989 trial run had an average downstream velocity of 3.0 km/h over 40 km from Dexter Dam to the Beltline bridge in Eugene. The rate of movement was slower during the first six hours of travel than during the second six hours. The highest velocity we observed for an individual fish was 8.1 km/h in a stretch of river we estimated to be flowing at 4.8 km/h. We followed six of 15 fish tagged in the second release group for a longer time; they traveled more or less in a group for 109 km at an average velocity of 3.4 km/h (Figures 7 and 8). Data are expressed as distance traveled downstream as a function of time; the slope of any line gives average velocity over a given stretch of river. While we located one fish several kilometers below Willamette Falls, we followed two others only 4.4 and 6.4 km downstream; these were probably alive as we caught untagged fish from the same release group in the area. The majority of fish moved downstream at a regular and rapid pace. The rest moved slowly or not at all; six fish were at the release site for 2.5 h or more. Thus 72 h after release, locations of our radio-tagged fish spanned 225 km on the river.

1990. In 1990 we released 31 tagged fish, of which 29 were detected at Clear-water Access (+16 km from release), 27 below Eugene (+37 km), 19 at Corvallis (+109 km), 17 at Buena Vista (+153 km), 18 at Independence (+171 km), seven at San Salvadore (+233 km), seven in the vicinity of Willamette Falls (+282 km), and six were encountered at various locations below Willamette Falls (Figure 9). One fish was tracked past Portland, almost to the confluence of the Willamette and Columbia Rivers (+319 km).

Tagged individuals began to move downstream immediately following release. Thirty minutes after the time of release, only one radio signal could be detected from the release site. In general, fish were observed to travel as a fairly tight group at a constant velocity of approximately 4.8 km/h as far downstream as Independence (Figure 10). In fact, this rather "linear" rate of movement was maintained as far downstream as San Salvadore by seven individuals recorded at that station. An interesting observation, not immediately obvious from inspection of Figure 9, is that fish constantly varied in their relative position or "order" maintained during this portion of the outmigration, i.e. the first fish recorded past a given tracking station was not always the first fish recorded past the next station. Below San Salvadore tagged individuals continued downstream toward Willamette Falls at reduced velocities (1.6 km/h or less).

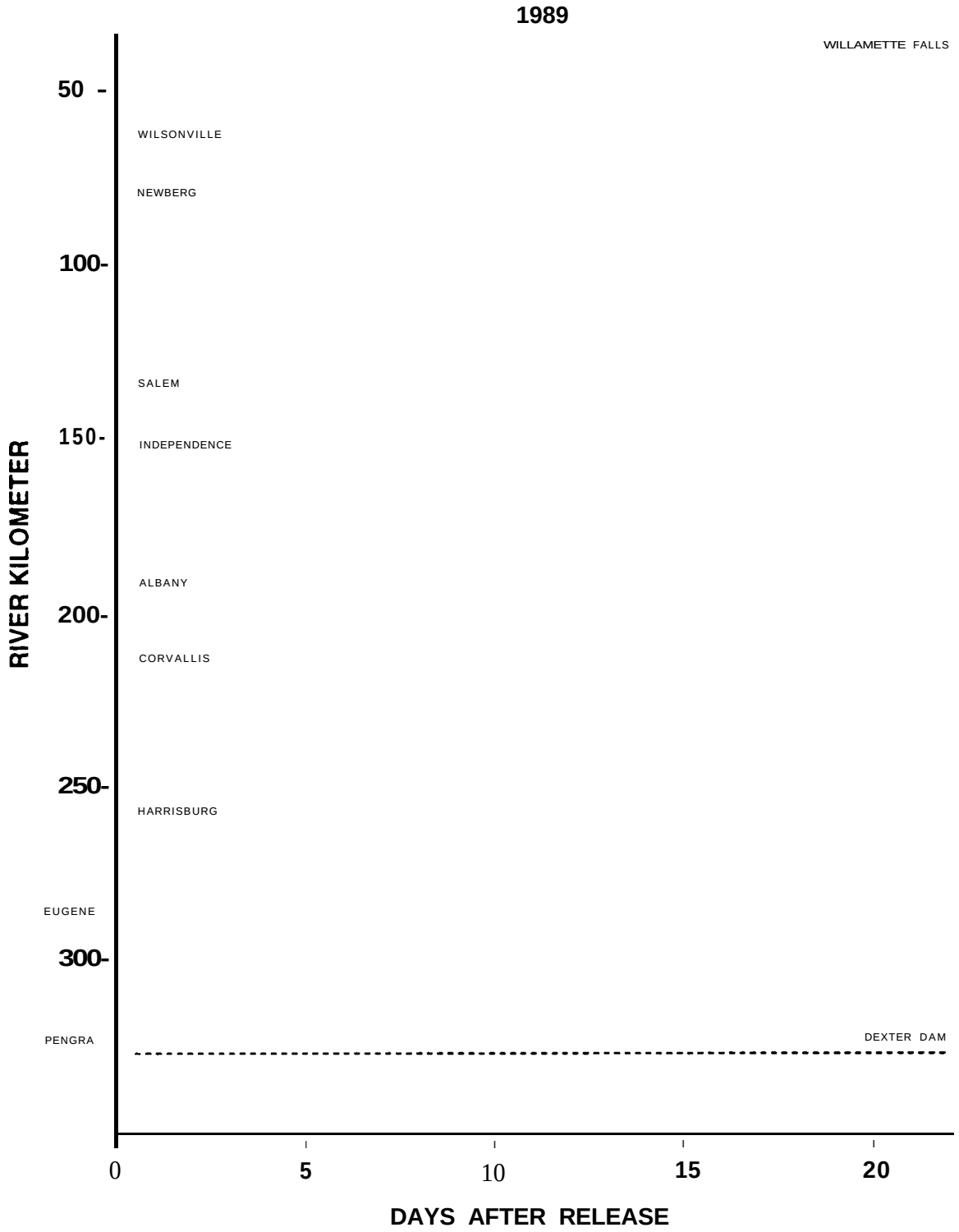


Figure 7. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamettr River at various days after release on 14 April 1989. Each line represents an individual fish N= 15 fish.

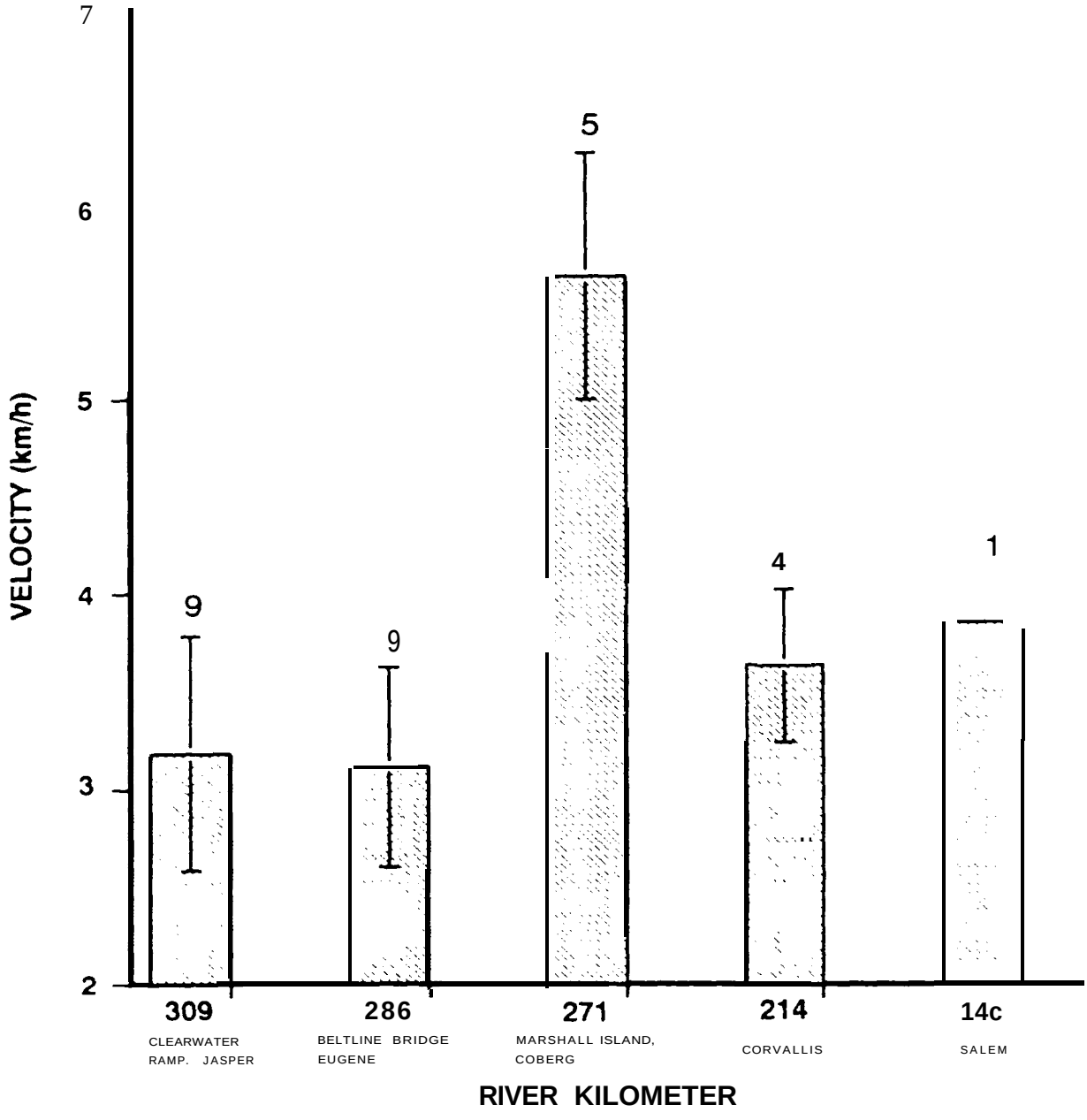


Figure 8. Mean outmigration velocity of radio-tagged smolts released on 14 April 1989. Velocity at locations along the outmigration in the Willamette River was determined by time/distance relationships between points. Number of fish for each mean shown at top of standard error bar.

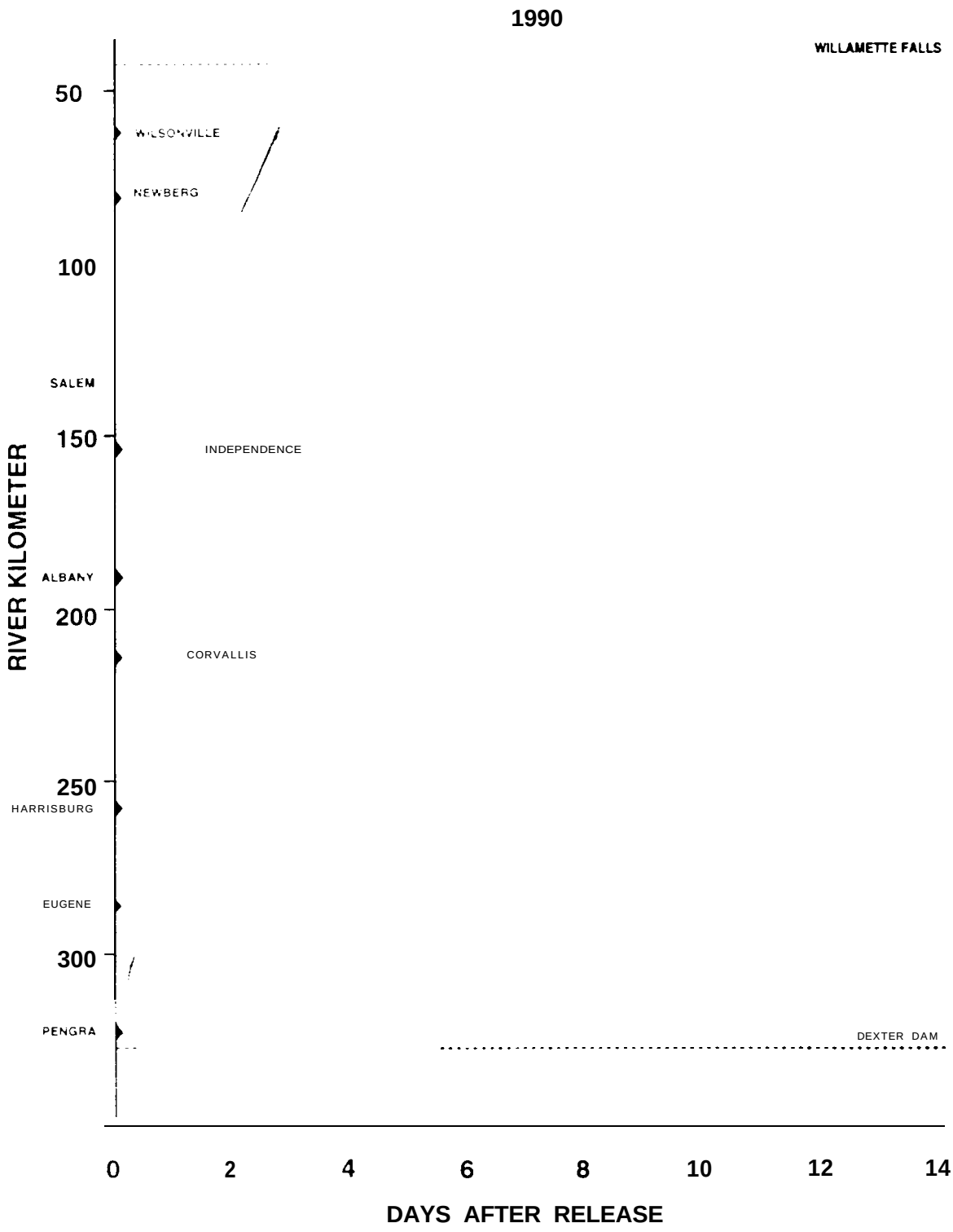


Figure 9. location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 1 2 March 1990. Each line represents an individual fish. N = 31 fish.

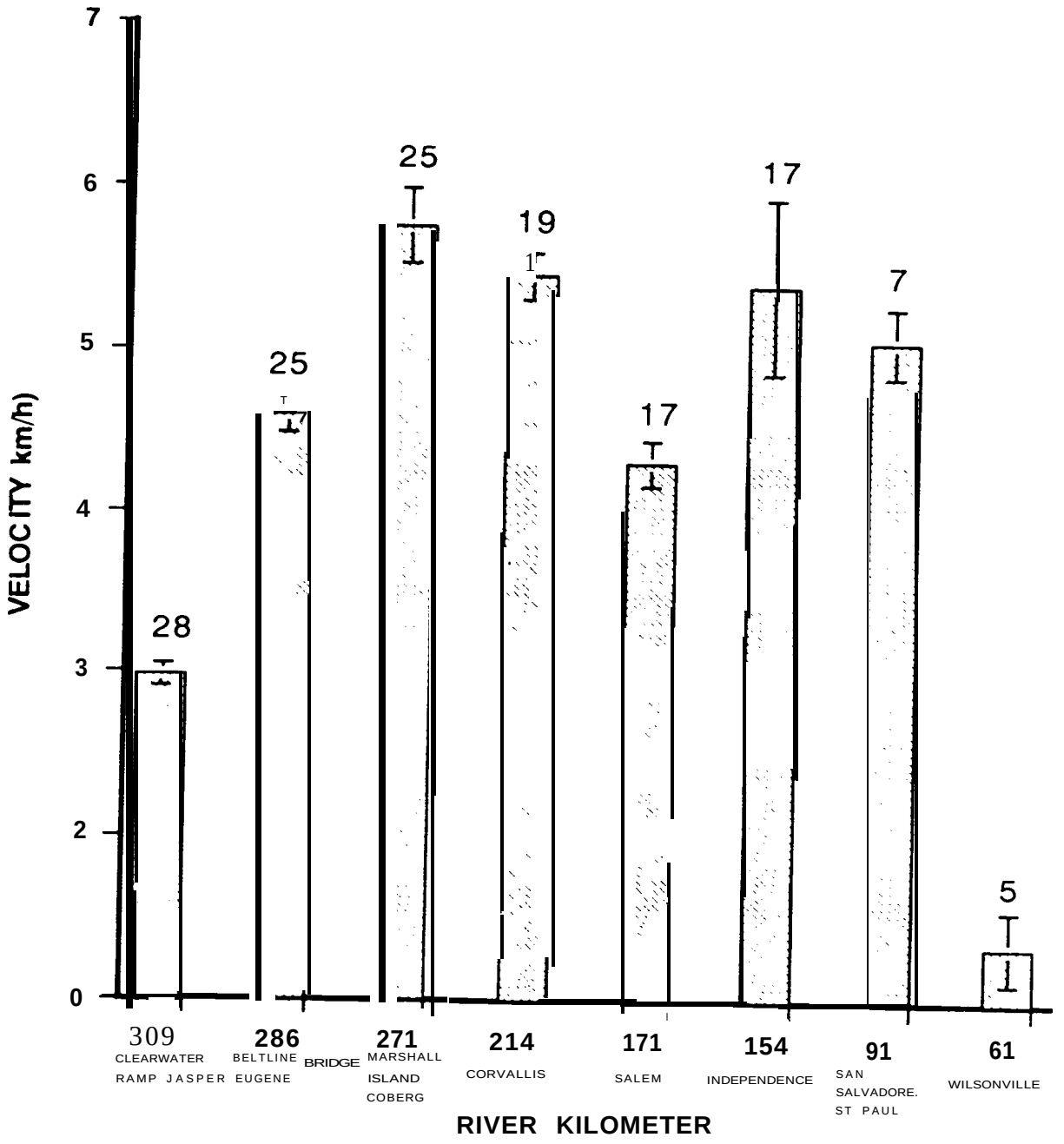


Figure 10. Mean outmigration velocity of radio-tagged smolts released on 12 March 1990. Velocity at locations along the outmigration in the Willamette River was determined by time/distance relationships between points. Number of fish for each mean shown at top of standard error bar.

and began to exhibit greater variability with respect to individual movement pattern.

Radio-tagged juveniles exhibited very interesting behavior in the immediate vicinity of Willamette Falls. While some fish moved over the Falls and were tracked past Portland, a number of individuals apparently ceased downstream movement entirely just above the Falls. These individual frequencies were monitored closely, and gradually "disappeared," presumably as these individuals resumed their seaward migration and proceeded downstream over the Falls. One was located above Willamette Falls 15 days after release, even though this particular fish first arrived at that spot less than four days after being liberated in the upper river.

Three individuals remained in the vicinity of the release site for almost two weeks. We feel confident that these were live, healthy fish (as opposed to either dead fish or regurgitated transmitters), as we were successful in capturing chinook smolts in this reach of river both by hook-and-line and electrofishing.

We were unable to determine whether or not outmigrant juveniles exhibited a pronounced diel pattern with respect to downstream movement. It was clear, however, that fish recorded past a given river-bank tracking station were in fact moving past that point, and fish were recorded past tracking stations both during daylight and night-time hours.

1991. Results of our 1991 radio telemetry studies on chinook smolt outmigration are presented in Figures 11-13. Fish velocities derived from regression analysis of these data are summarized in Figure 14 together with estimates of river current velocities. Of the 60 fish tagged with radio transmitters, 42 were successfully tracked downstream of the release site over a period of seven days. Fifteen of these represented the standard treatment, 12 represented the triple density treatment, and 15 represented the third Michigan treatment.

Although the majority of tagged juveniles began to move downstream immediatelv following release, 12 fish (two each standard and triple density treatments, and five each from third Michigan treatments) remained within receiving range of the release site for at least 1.5 hours after liberation.

Fish traveled at velocities of 3.2 to 4.8 km/h as far downstream as Willamette Mission Park (RKM 116). No differences were observed between treatment groups with respect to rate of downstream movement. In general, fish tended to travel faster in the upper river (5.6 km/h in the vicinity of Harrisburg, RKM 259), than in the lower river (1.9 km/h in the vicinity of Wilsonville, RKM 60) corresponding to reduced current velocities in the lower river. Fish constantly varied in their relative position or "order" during the outmigration; the first fish recorded past a given tracking station was not always the first fish recorded past the next station.We could not assess whether outmigrant

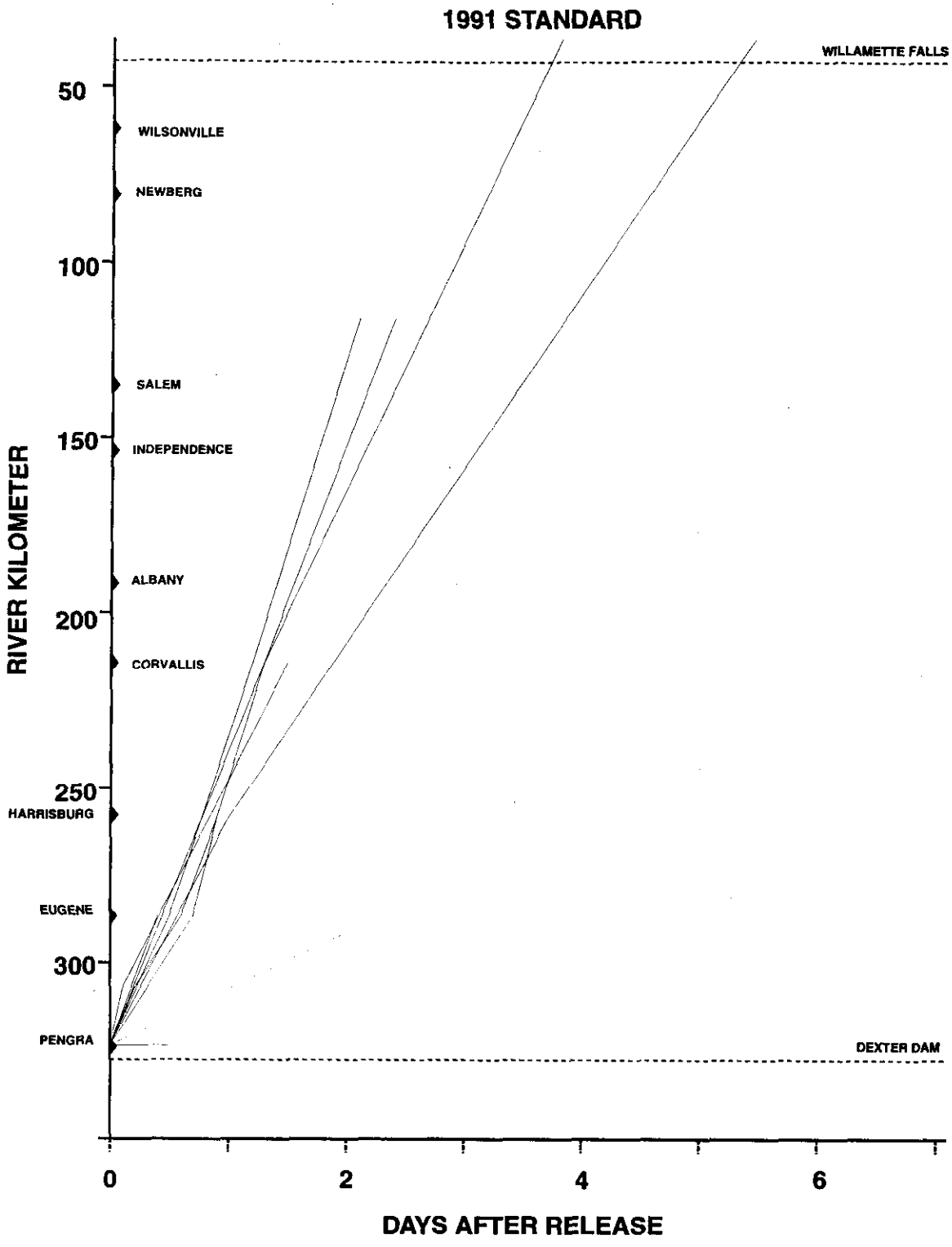


Figure 11. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 1 March 1991. Each line represents an individual fish from the standard treatment. N = 15 fish.

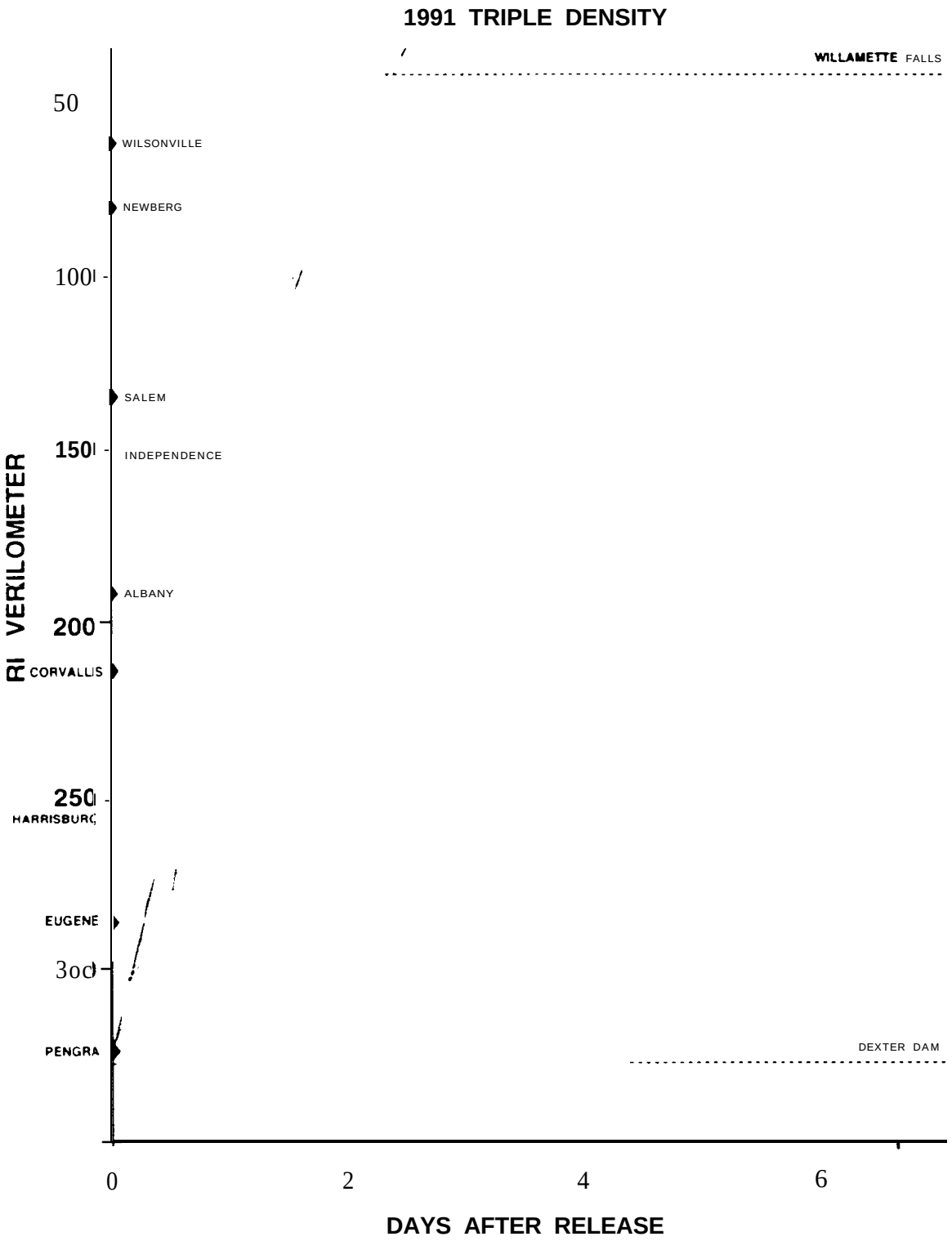


Figure 12. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 1 March 1991. Each line represents an individual fish from the triple density treatment. N = 12 fish.

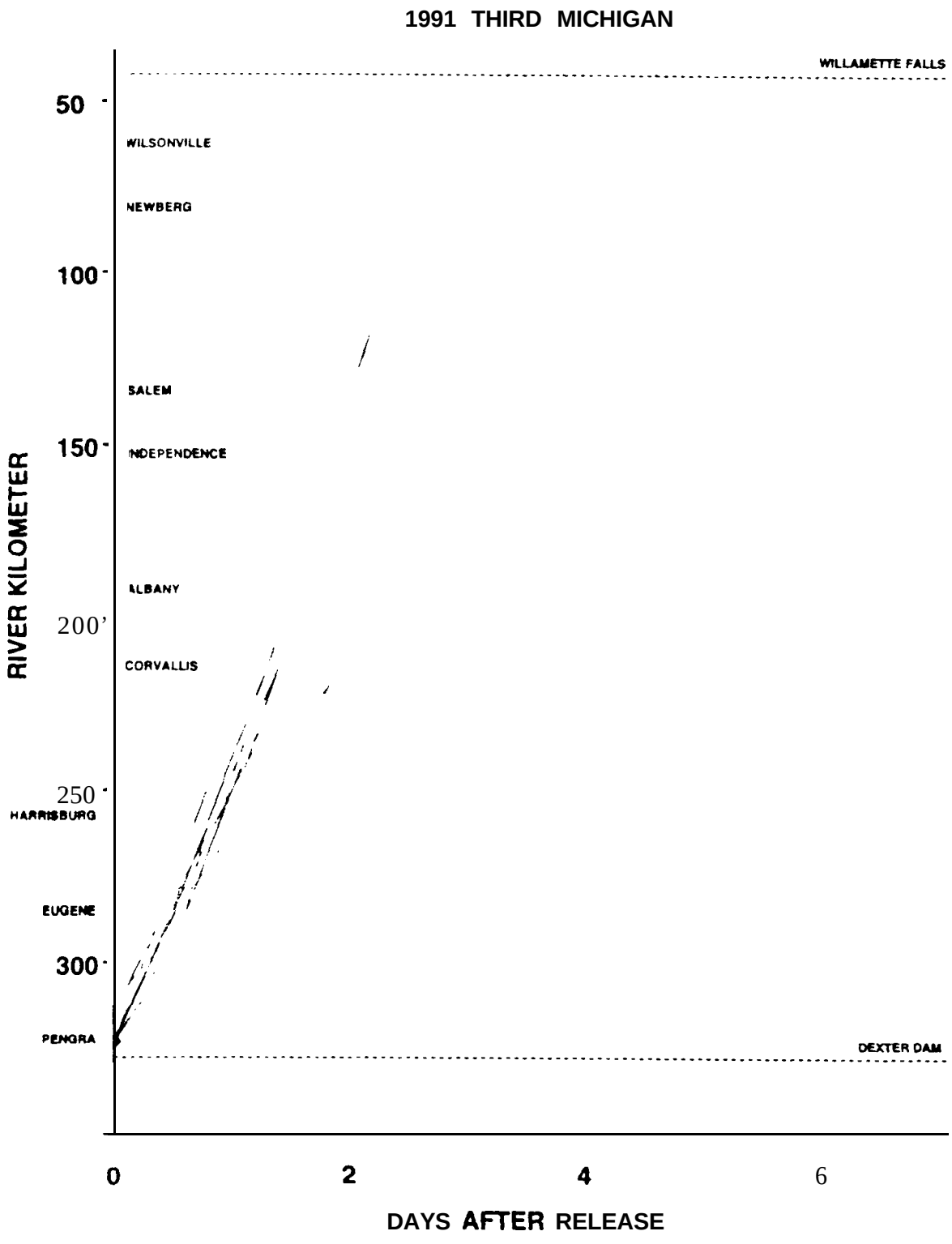


Figure 13. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 1 March 1991. Each line represents an individual fish from the third Michigan treatment. N = 15 fish.

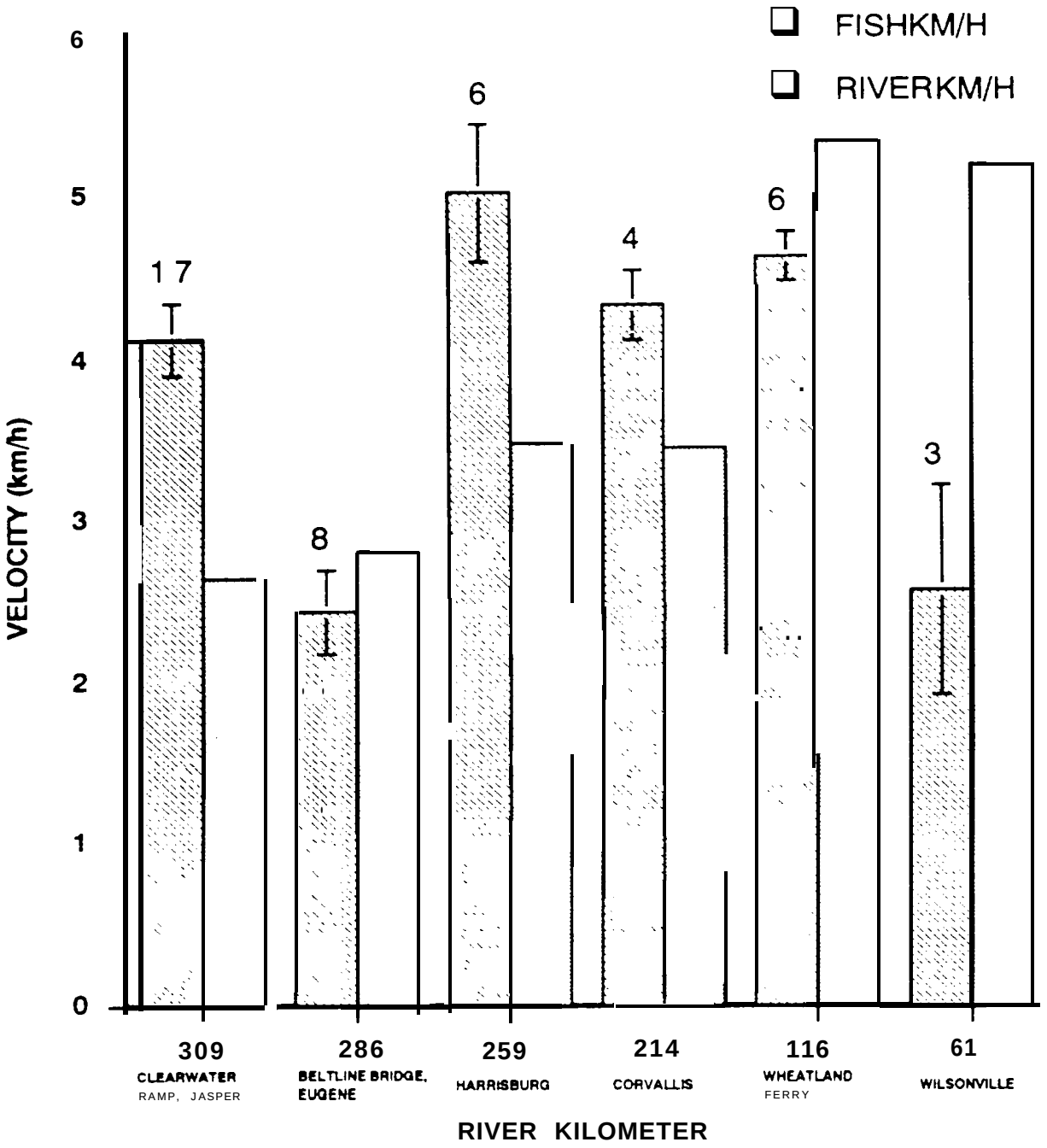


Figure 14. Willamette River current velocities and rates of downstream movement observed for radio-tagged juvenile spring chinook salmon (treatments combined) during outmigration, 1991. Fish velocities at locations along the outmigration were determined by time/distance relationships between points calculated from regression analysis of tracking data. River velocities estimated using a Marsh-McBirney flow meter (see text).

juveniles exhibited a pronounced diel pattern with respect to downstream movement, but fish were recorded past tracking stations both during daylight and darkness.

1992. The dispersal of smolts released with radio transmitters on 2 March 1992 is presented in Figures 15-17 and their velocities in Figure 18. Reliability of these data suffers from the transmitter failure we encountered (see Methods), for we cannot be certain which radios failed and when they failed. Of the 18 fish tagged with radio transmitters which functioned the first day, we successfully tracked nine 18 km downstream of the release site, and two reached Willamette Falls 319 km downstream. Seven of 18 fish (three from the standard treatment, five from the triple density treatment, and four from the third Michigan treatment) remained within 4.8 km of the release site for at least 12 h after liberation.

Those fish from standard and third Michigan treatments which moved did so at two rates, a fast group averaging 5.5 km/h and a slow group averaging 1.6 km/h between Eugene and Corvallis. At Newberg (RKM 79), where the Willamette River begins to pool, the four fast-migrating smolts slowed to 2.6 km/h; the slower group of fish did not reach here within the expected life of their transmitter batteries. As in previous years fish constantly varied in their relative position or "order" during the outmigration and moved both day and night.

Results for the second release of radio-tagged smolts, on 24 March 1992, are found in Figures 19-22. Since these fish were removed from their treatment groups on 2 March (for later tagging and release), any suggested differences between groups must be viewed with caution. With decreased river flow, the earliest of these fish arrived at Willamette Falls 18 days after release, in contrast to 6 days for the first release (see below also). Fish from the Standard treatment moved most rapidly, but we tracked none further than the Newberg Pool (RKM 55); average velocities to here were about 1 km/h. Although sample sizes are small for the others, radio-tagged fish reared under triple density treatment traveled further, and third Michigan treated fish the shortest; average fish velocities as far as Harrisburg were 0.3 km/h.

Detailed observations on individuals fish in 1992 suggested that smolts often rested and fed in the afternoon. They fed just downstream of riffles, in expected "trout" feeding lanes. During these times there were many other salmonids in these areas, feeding actively on the surface. In late afternoon radio-tagged fish which were in these areas resumed their outmigration. Smolts apparently moved in discrete periods of activity, representing hours. Therefore an outmigration time of six days represents periods of movement as well as periods of feeding and/or resting.

1993. The patterns of outmigration of radio-tagged smolts in 1993 are found in Figures 23-26, with velocities in Figure 27. We were successful in recording the

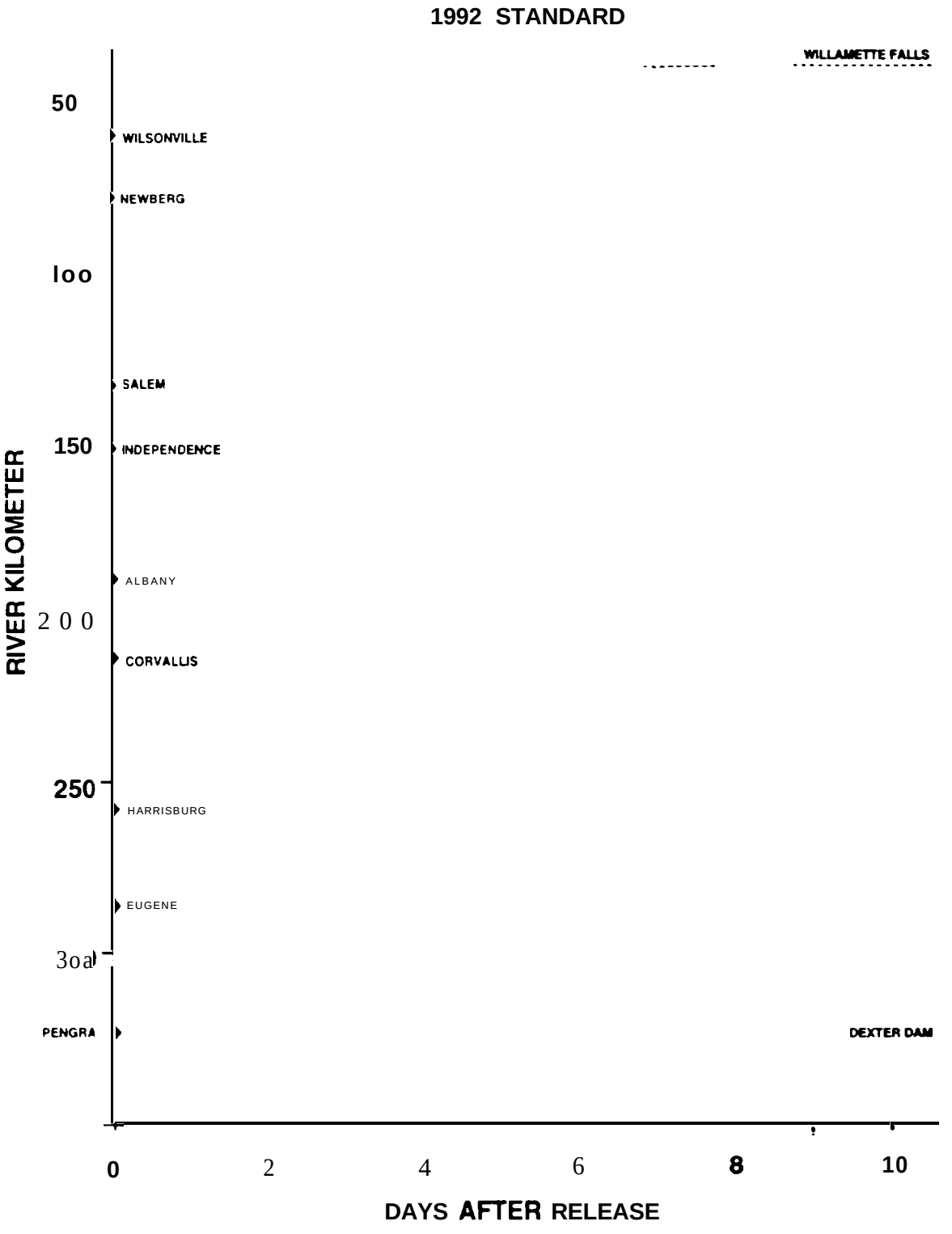


Figure 15. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 2 March 1992. Each line represents an individual fish from the standard treatment. N = 5 fish.

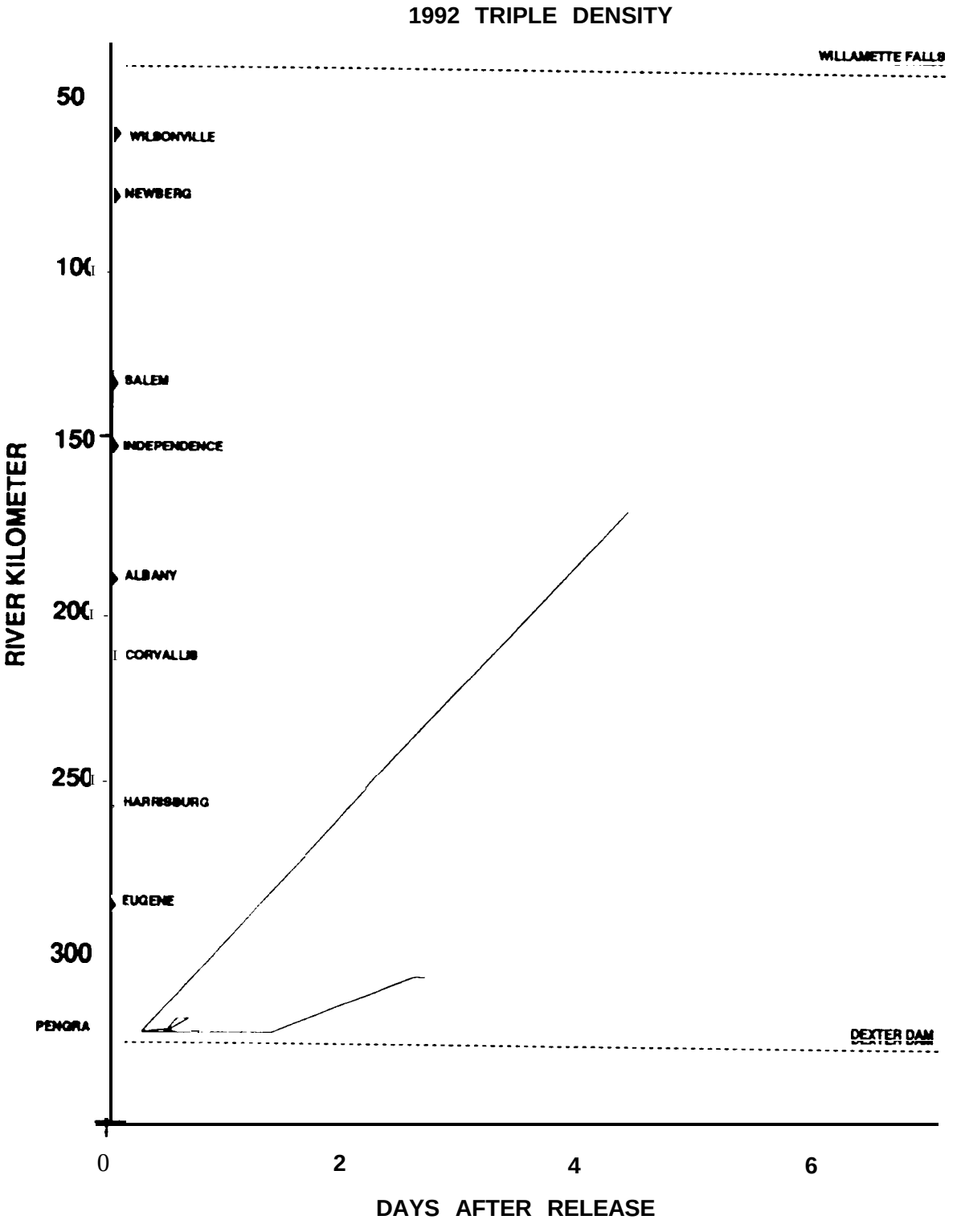


Figure 16. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 2 March 1992. Each line represents an individual fish from the triple density treatment. N = 5 fish.

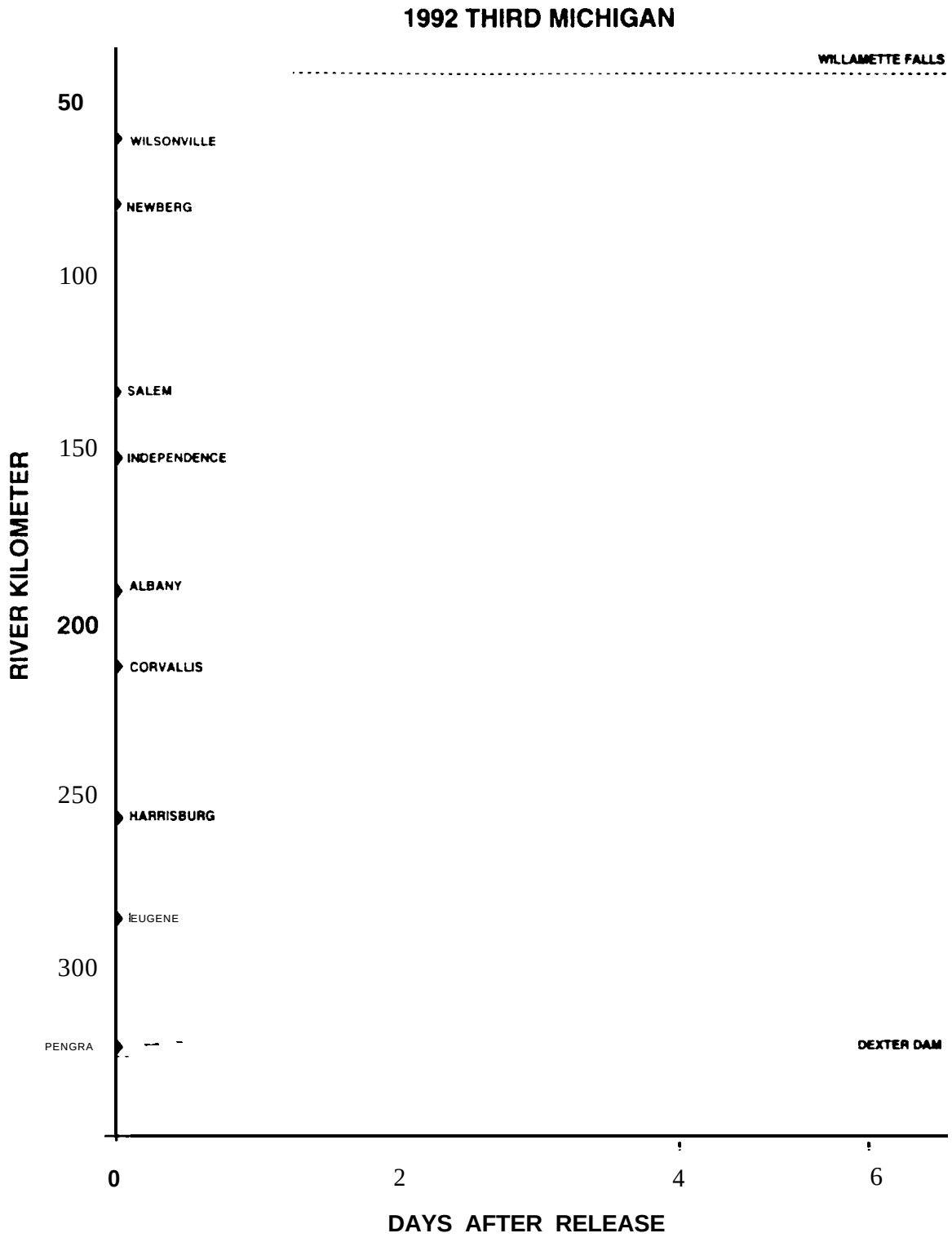


Figure 17. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 2 March 1992. Each line represents an individual fish from the third Michigan treatment. N = 8 fish.

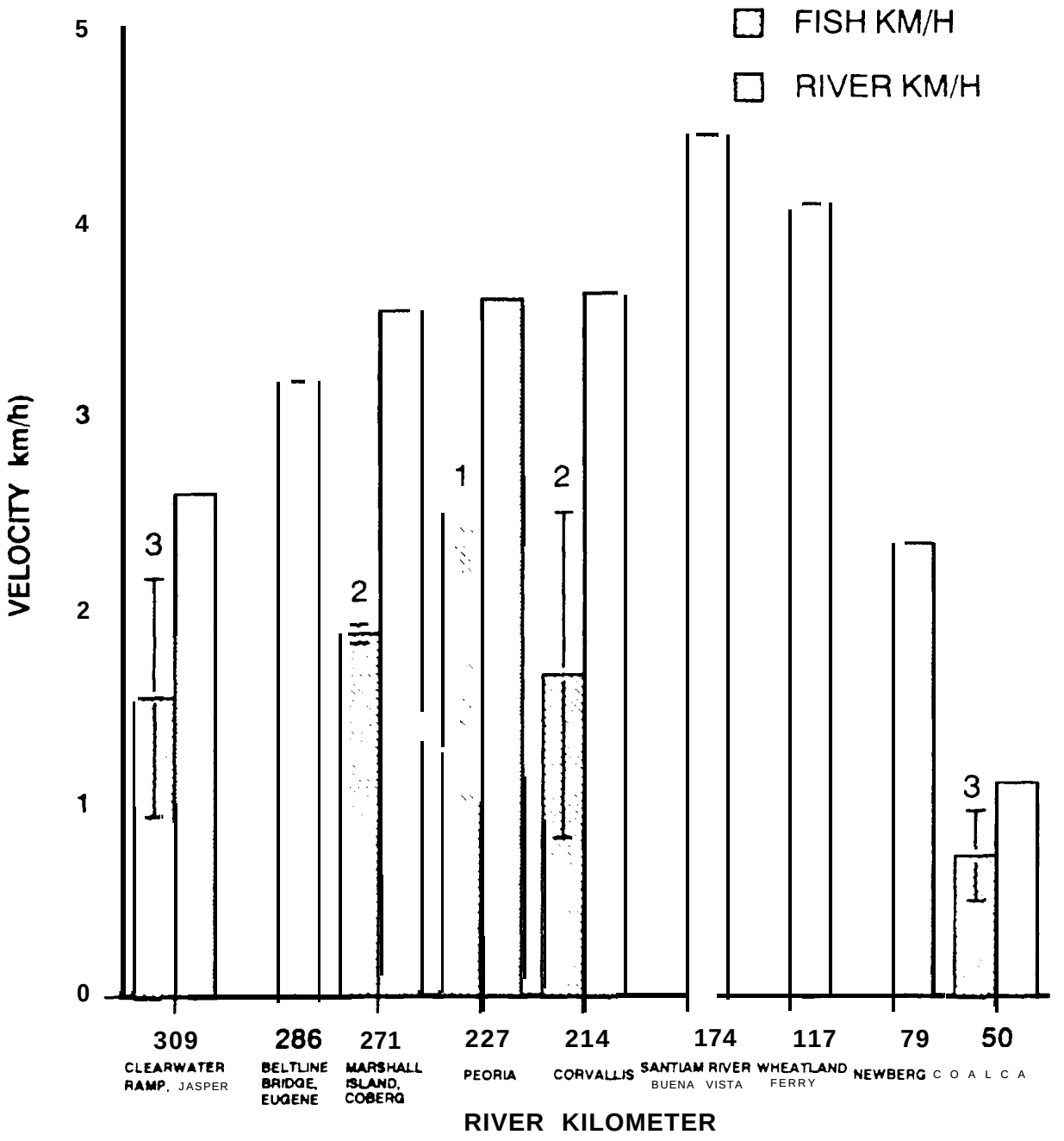


Figure 18. Willamette River current velocities and rates of downstream movement obsened for radio-tagged juvenile spring chinook salmon during outmigration, 1992. Fish velocities at locations along the outmigration were determined by time/distance relationships between points calculated from regression analysis of tracking data. Velocities of fish from each treatment were combined. River velocities estimated using a Marsh-McBirney flow meter (see text).

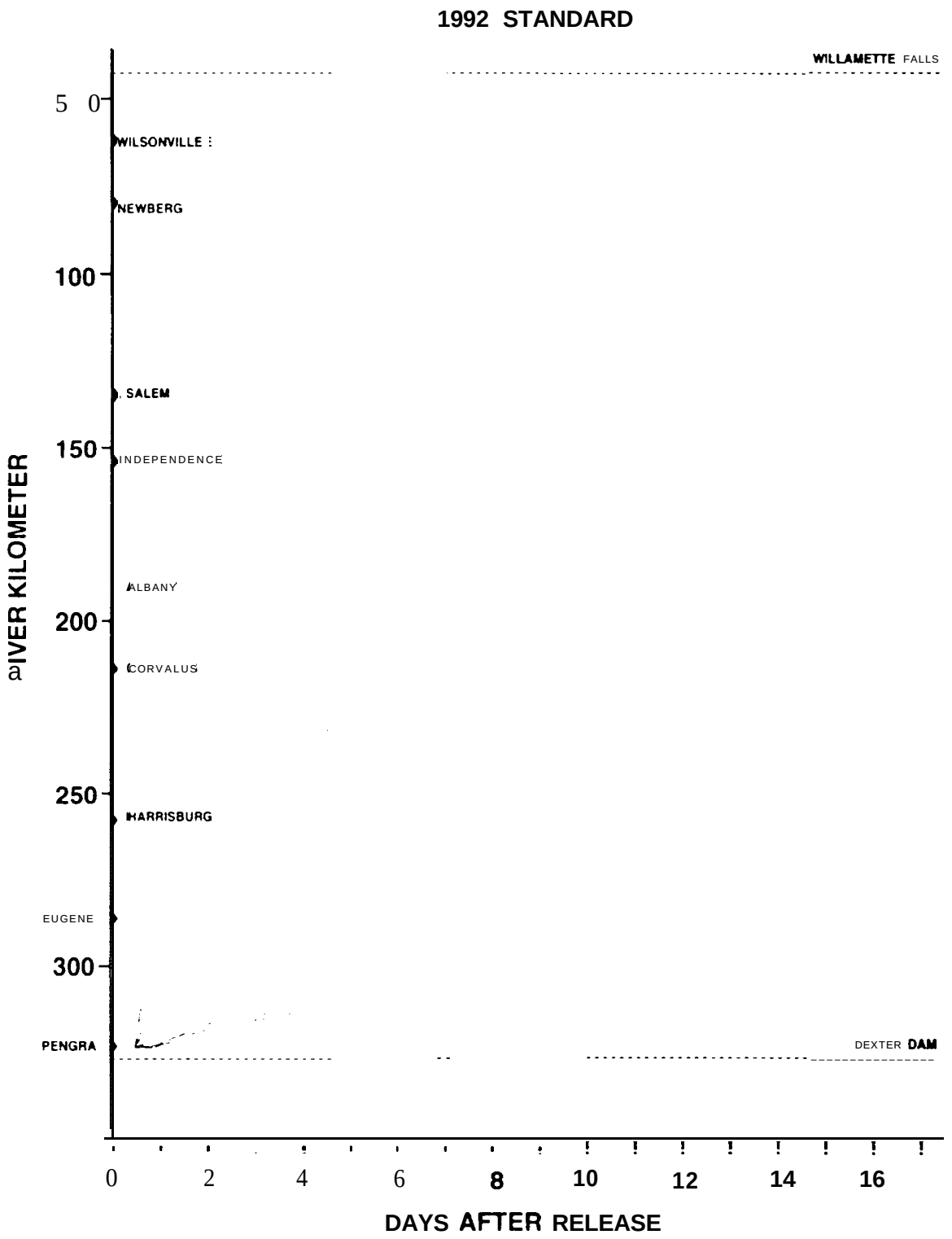


Figure 19. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 24 March 1992. About 100 fish were netted from outdoor raceways on 1 March and transferred to indoor troughs. We tagged 17 of these on 20 March Each line represents an individual fish from the standard treatment. N = I7 fish.

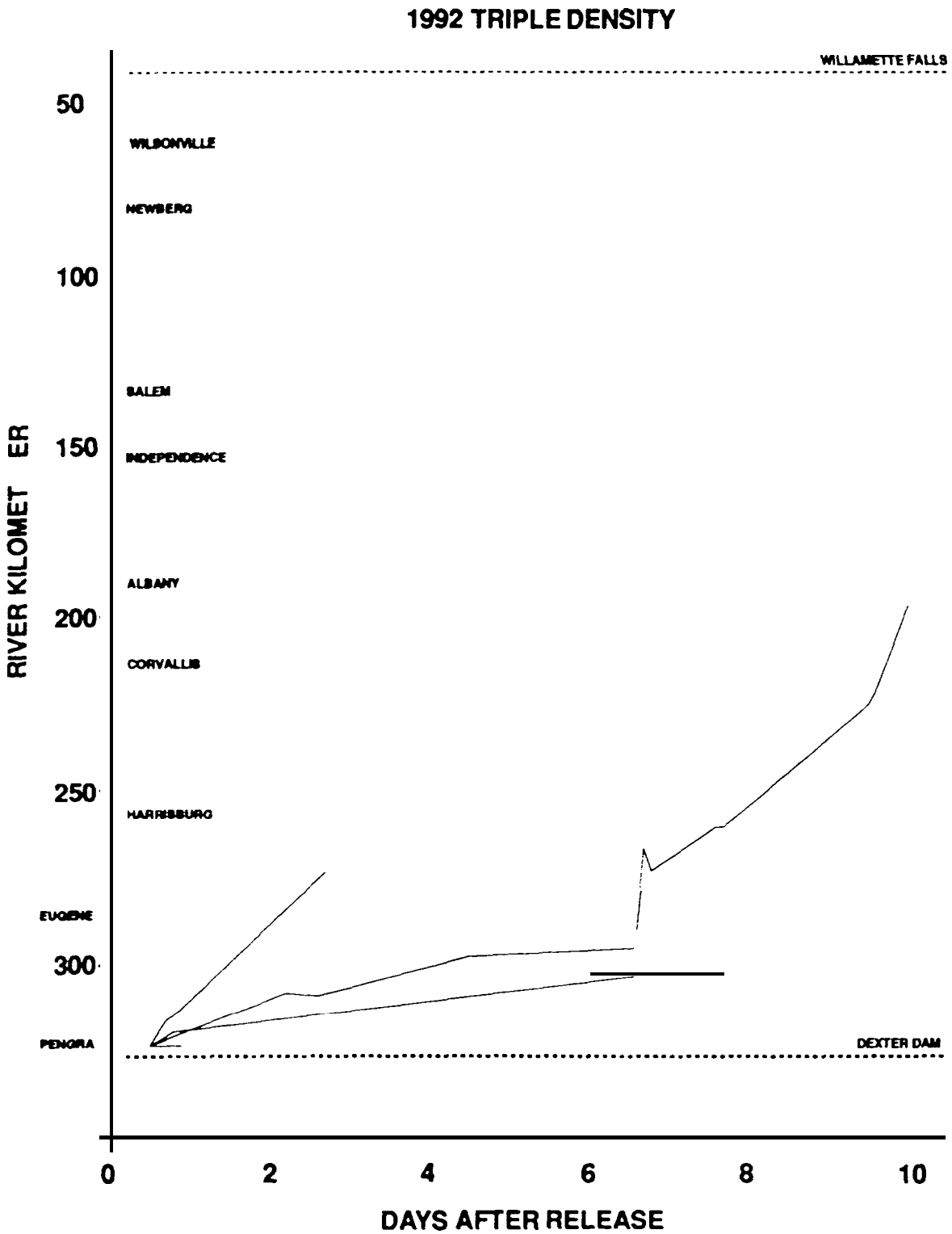


Figure 20. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 24 March 1992. About 100 fish were netted from outdoor raceways on 1 March and tranferred to indoor troughs. We tagged four of these on 20 March. Each line represents an individual fish from the triple density treatment. N = 4 fish.

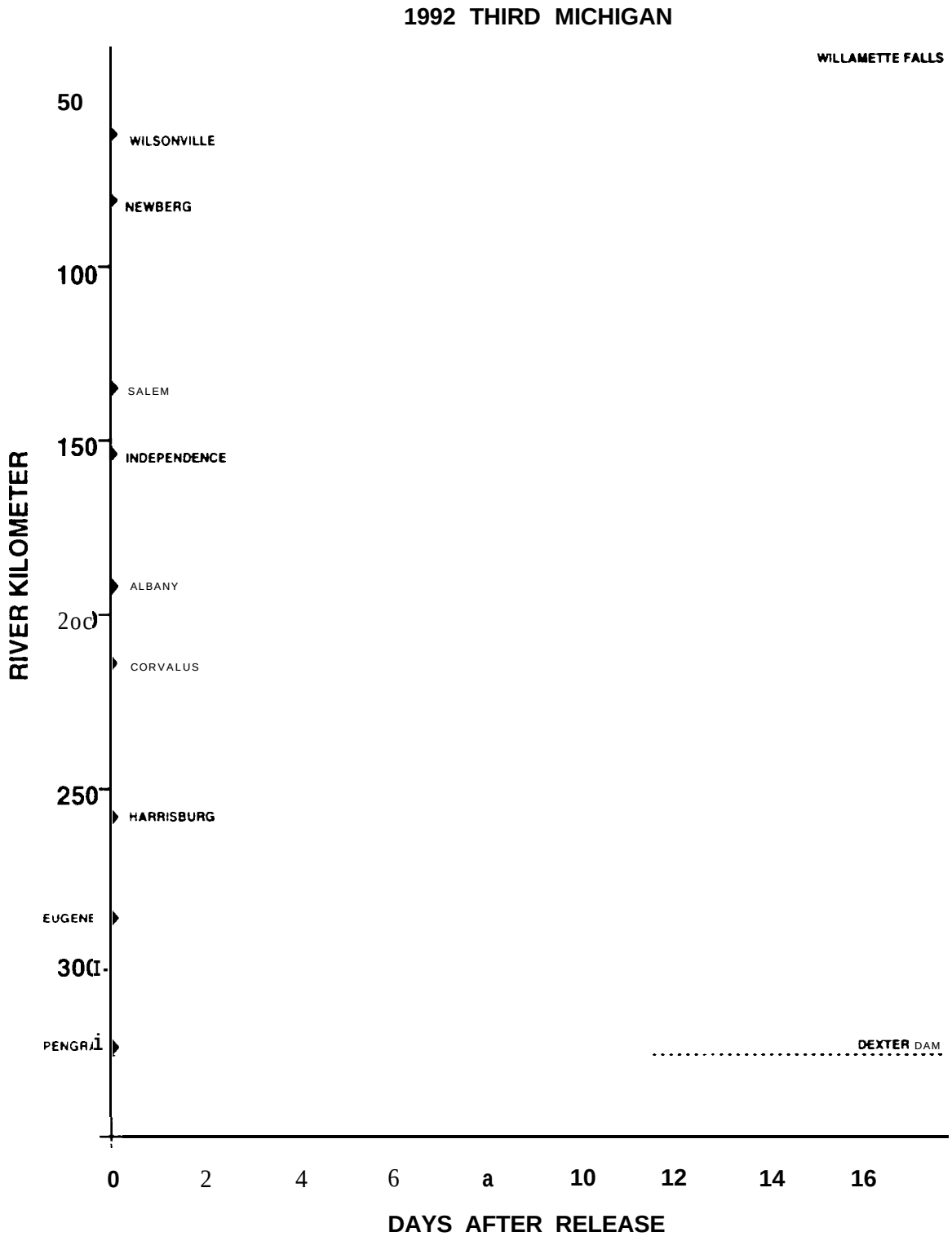


Figure 21. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 24 March 1992. About 100 fish were netted from outdoor raceways on I March and transferred to indoor troughs. We tagged five of these on 20 March Each line represent an individual fish from the third Michigan treatment. N = 5 fish.

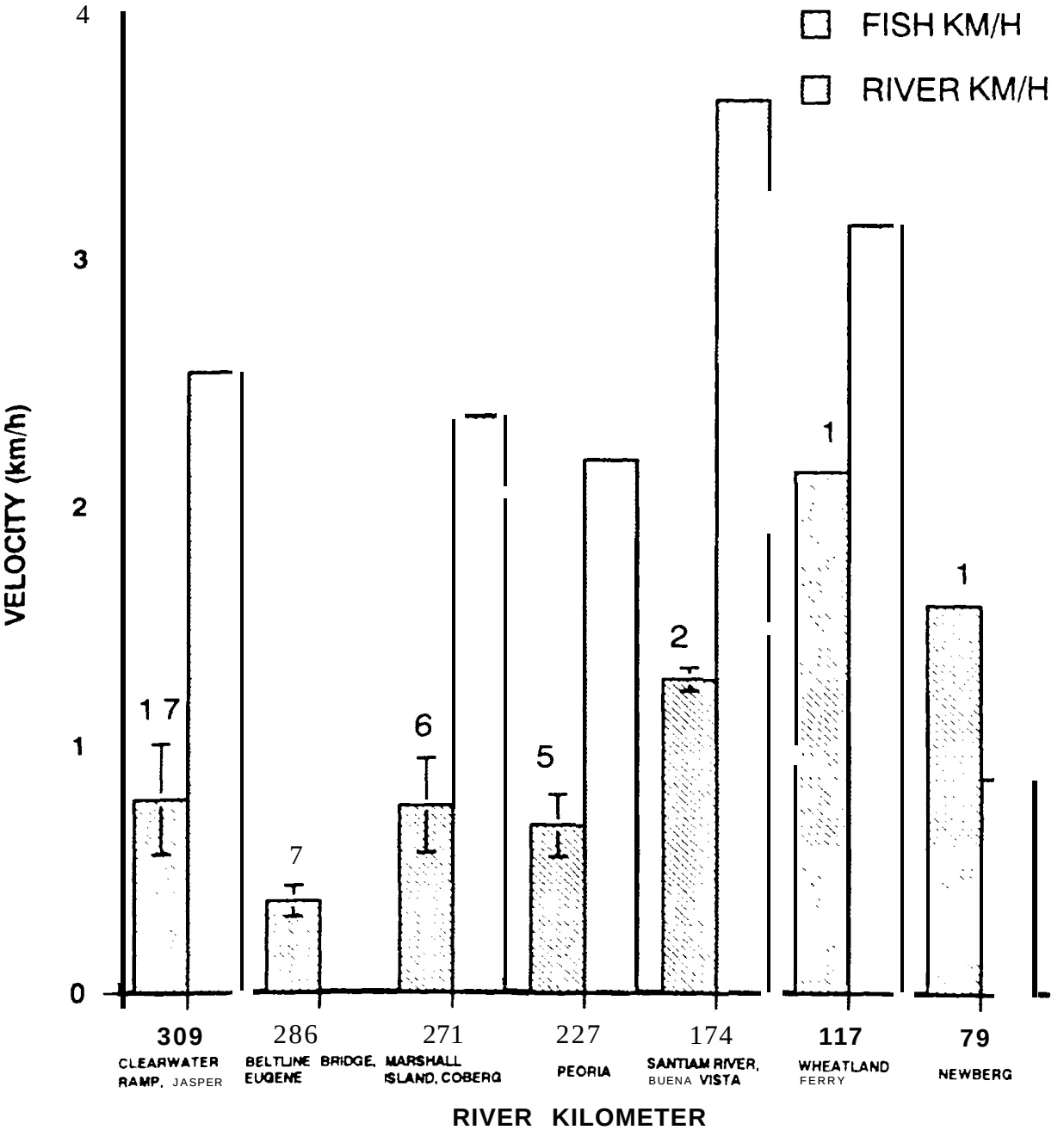


Figure 22. Willamette River current velocities and rates of downstream movement observed for radio-tagged juvenile spring chinook salmon during outmigration, 1992. About 100 fish were netted on 1 March and transferred to indoor troughs. We tagged 26 of these on 20 march and released them at Pengra Ramp (Willamette RKM 323 on 24 March 1992 (see text). Fish velocities at locations along the outmigration were determined by time / distance relationships between points calculated from regression analysis of tracking data. Velocities of fish from each treatment were combined. River velocities estimated using a Marsh-McBirney flow meter (see text).

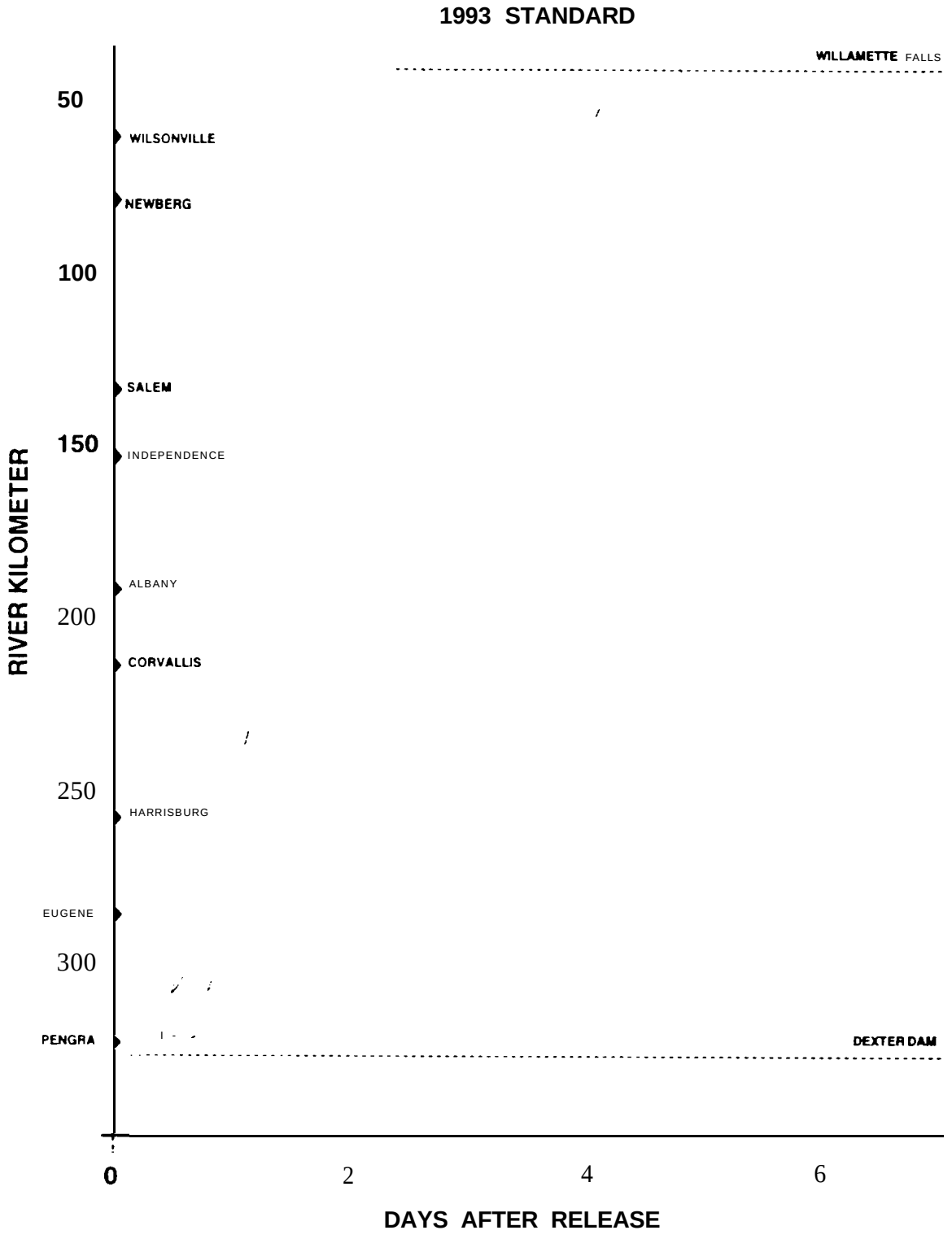


Figure 23. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 15 March 1993. Each line represents an individual fish from the standard treatment. N = 19 fish.

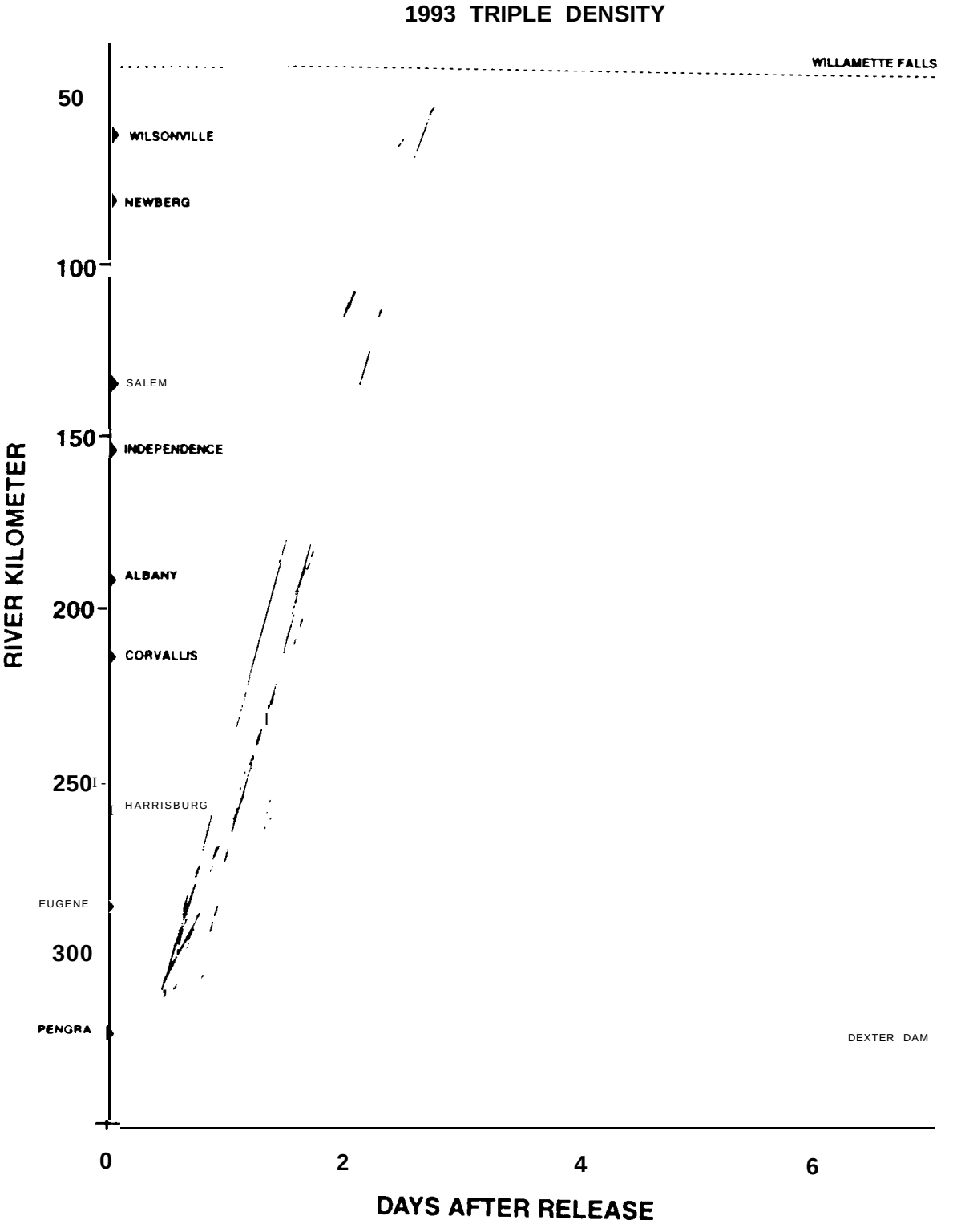


Figure 24. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 15 March 1993. Each line represents an individual fish from the triple density treatment. N = 18 fish.

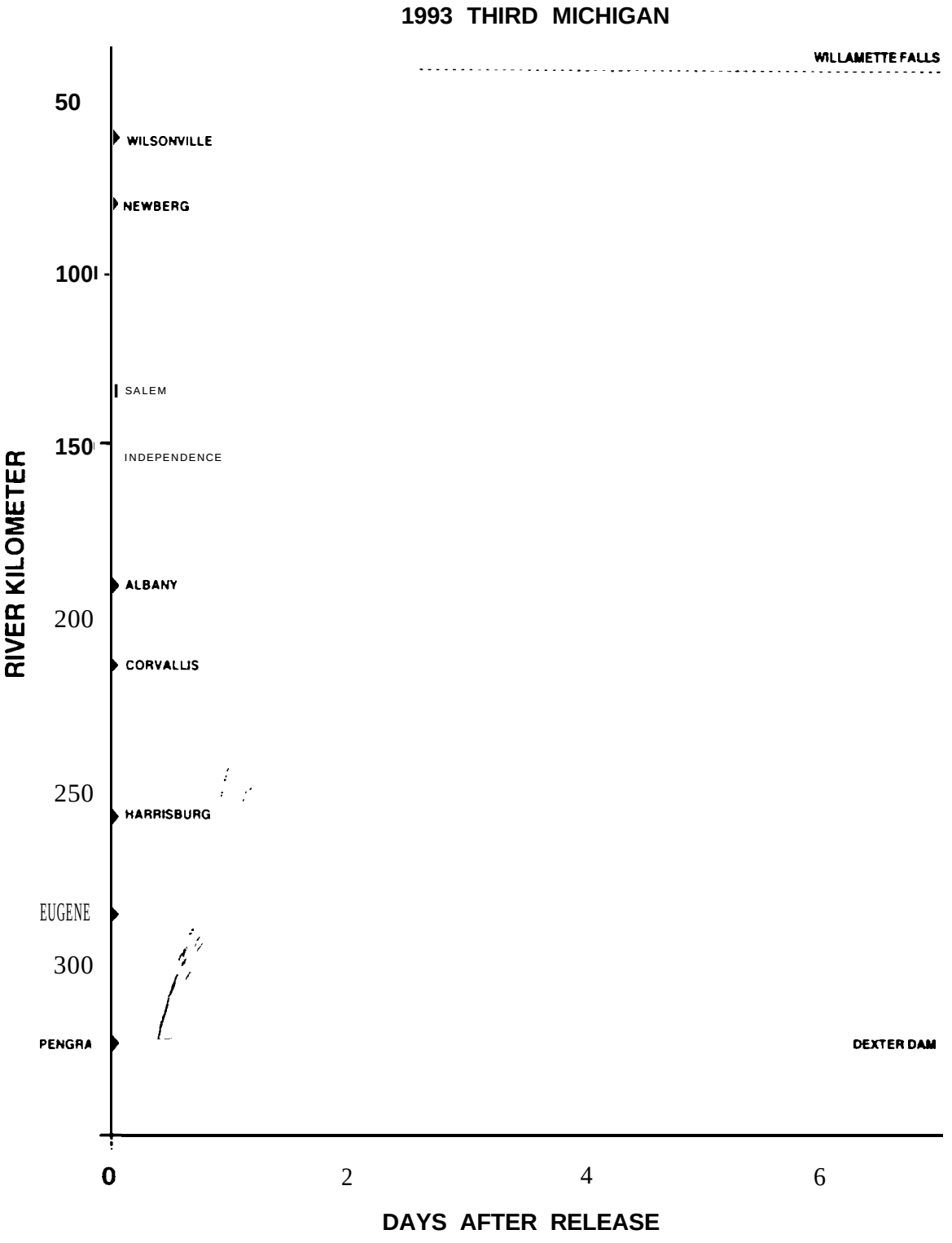


Figure 25. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 15 March 1993. Each line represents an Individual fish from the third Michigan treatment. N = 18 fish.

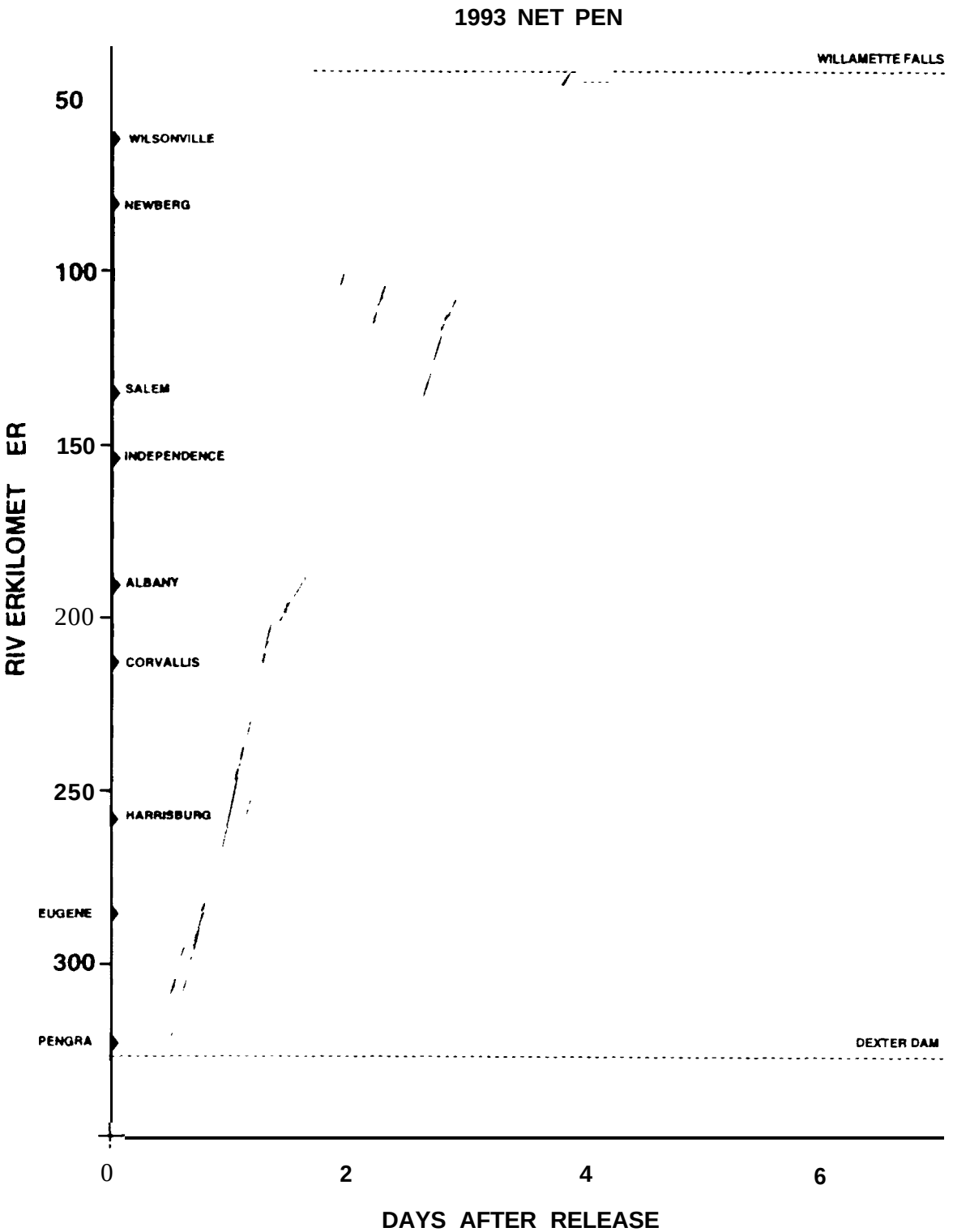


Figure 26. Location of radio-tagged outmigrant juvenile spring chinook salmon in the Willamette River at various days after release on 15 March 1993. Each line represents an individual fish from the standard treatment which were placed in a net pen 0.5 km below Pengra Ramp on 12 March and released at the same time as the other tagged fish released that day (see text). N = 10 fish.

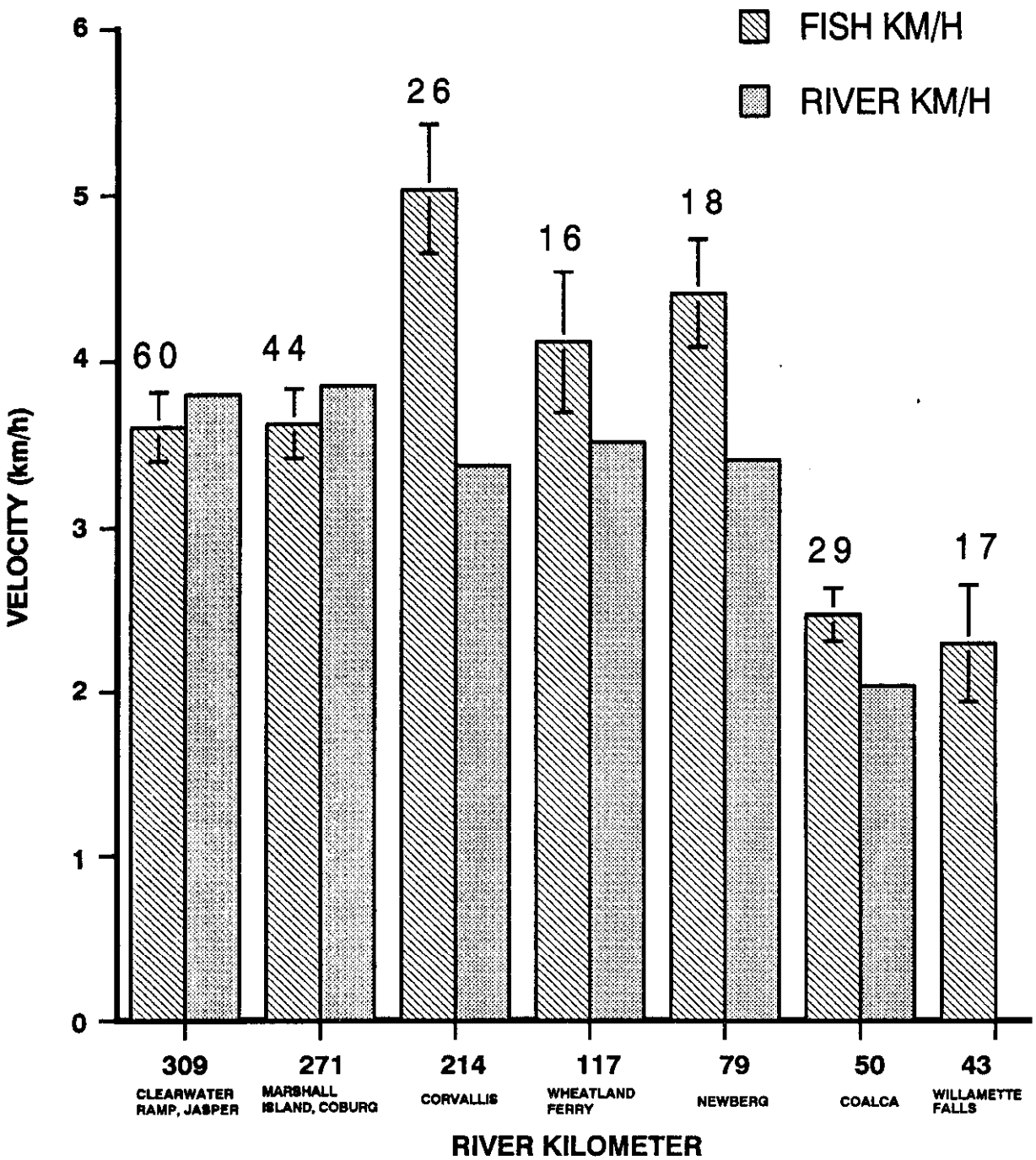


Figure 27. Willamette River current velocities and rates of downstream movement observed for radio-tagged juvenile spring chinook salmon during outmigration, 1993. Fish velocities at locations along the outmigration were determined by time/distance relationships between points calculated from regression analysis of tracking data. Velocities of fish from each treatment were combined. River velocities estimated using a Marsh-McBirney flow meter (see text).

majority of fish nearly all the way to Willamette Falls this year. We tracked 11 of 20 radio-tagged fish from the standard and triple density treatments to within 6 km of Willamette Falls, 10 of 20 fish from the third Michigan treatment, and all of the 10 fish from the standard treatment released from the net pen at Pengra Access. About 30% of the fish liberated by ODFW from Pengra Access site and those from the net pen, and as few as 5-15% from third Michigan and triple density treatments remained within hearing distance of the release point for more than two hours. The majority of the radio-tagged fish outmigrated 282 km to Willamette Falls at an average velocity of 3.9 km/h. Two fish each in the standard, triple density and third Michigan treatment groups traveled at only half that speed (about 2 km/h). There were no apparent differences in migration pattern between the treatment groups.

Environmental Conditions During Outmigration.

The Willamette River flow at Pengra Ramp where most smolts were liberated is determined by water released from the Corps of Engineers dam at Dexter, and by rainfall. The flow (at Salem) and temperature (at Willamette Falls) for the years of our releases are shown in Figures 28-32. In all years the river temperature was steadily rising or remained constant during smolt outmigration. Both of our releases of fish in 1989 occurred as river flow was receding from 40,000 cfs (first release) to 30,000 cfs (second release) and toward summer lows. The single release in 1990 also took place during flows receding from 20,000 cfs. In 1991, by contrast, smolt releases coincided with a major period of rainfall, as flow jumped from 13,000 to 60,000 cfs in five days; radio-tagged fish reached Willamette Falls before the river crested, however. In 1992 smolt releases again coincided with low, declining flows, 17,000 cfs for the first release and 9,000 cfs for the second. 1993 was much like 1991, but the onset of the freshet was much faster, as smolt releases occurred during a major freshet with flows increasing from 18,000 to 80,000 cfs over five days.

Fish Velocities and River Velocities.

Direct measurements of smolt out migration speed and estimates of river velocity (where available) are found in Figures 8, 10, 14, 18, 22, and 27. In 1989 we calculated the outmigration speed of smolts in a small data set from Pengra Access to just below Salem. Outmigration of about 3 km/h was observed to Beltline Bridge, with a dramatic increase to nearly 6 km/h between Beltline and Marshall Island. From there to Salem speeds were from 3 to 3.5 km/h.

In 1990 a more complete data set of smolt observations was available from Pengra Access to Wilsonville. Fish velocity from Pengra to Clearwater Access was 3 km/h, and between San Salvadore and Wilsonville, just 1 km/h. In the

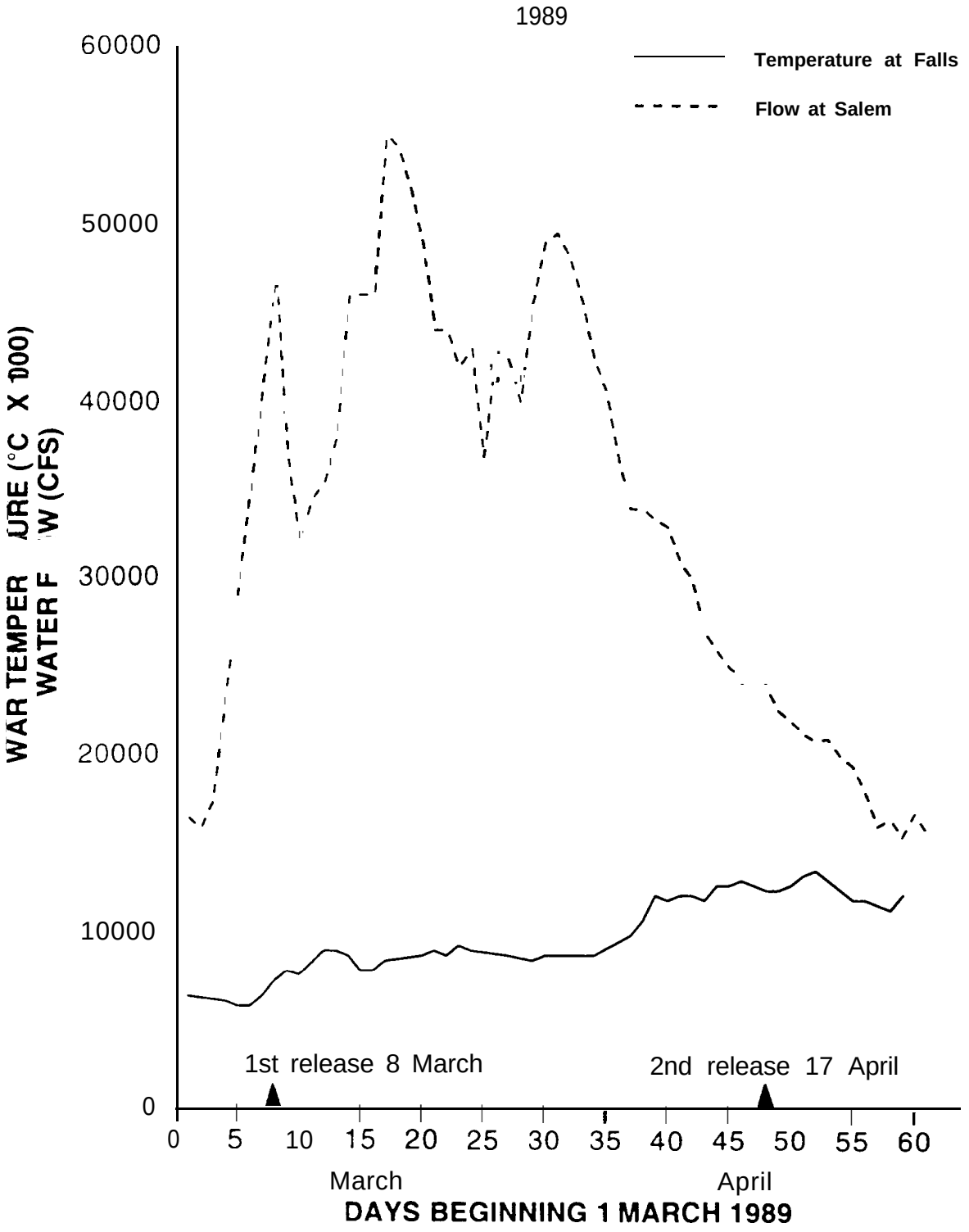


Figure28. Water temperatures and flow rates describing the Wellamette River during outmigration of radio-tagged juvenile spring chinook salmon in 1989. Water temperatures recorded at Willamette Ralls (RKM 43) prov ided by ODFW; water flows recorded at Salem (RKM 1 35) provided by the US Geological Survey.

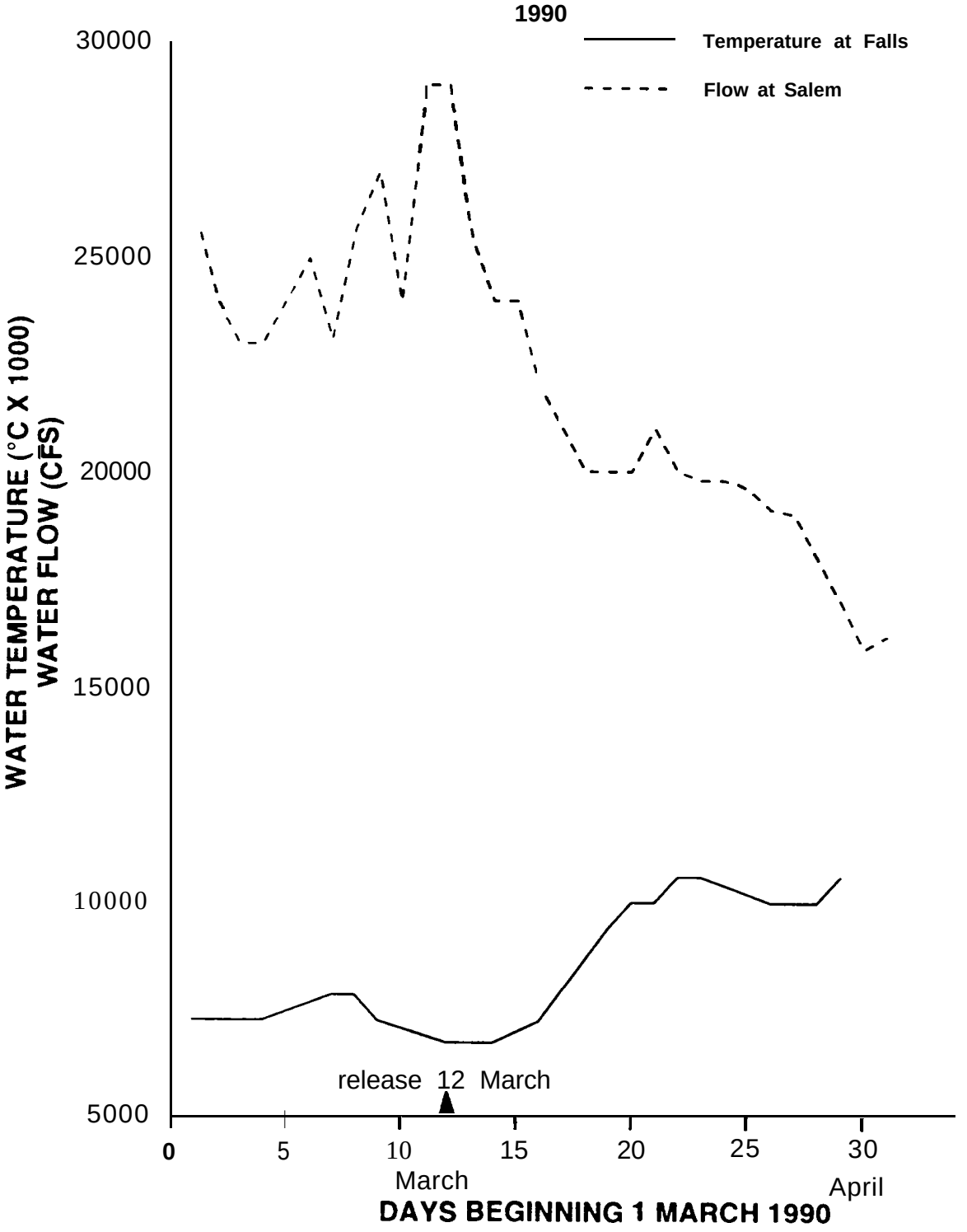


Figure29 Water temperatures and flow rates describing the Willamette River during outmigration of radio-tagged juvenile spring chinook salmon in 1990. Water temperatures recorded at Willamette Ralls (RKM 43) provided by ODFW: water flows recorded at Salem (RKM 135) provided by the US Geological Survey.

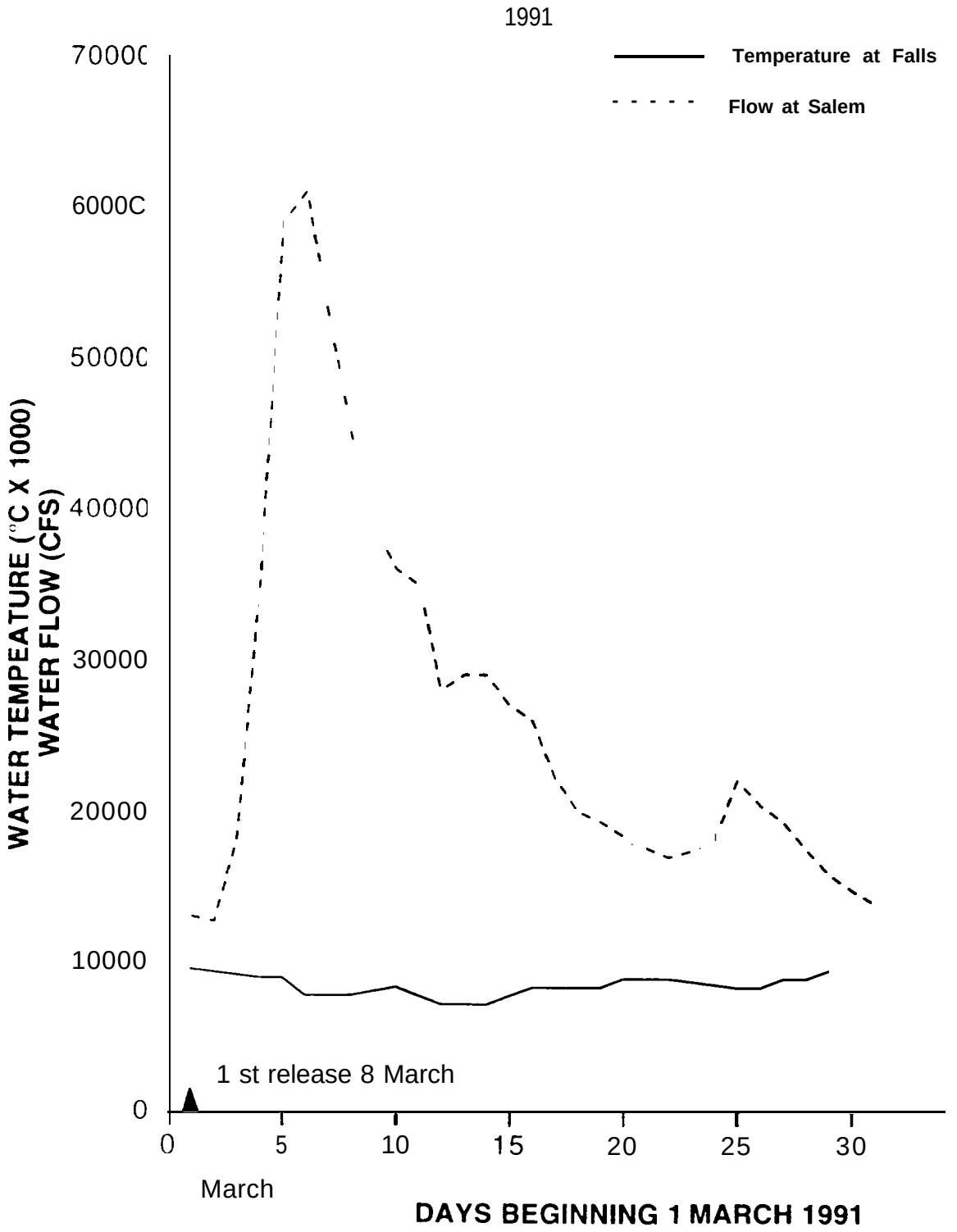


Figure 30. Water temperatures and flow rates describing the Willamette River during outmigrat ion of : radio-tagged juvenile spring chinook salmom in 1991. Water temperatures record ed at Willamette Ralls (RKM 43) provided by ODFW: water flows recorded at Salem (RKM I 135) provided by the US Geological Survey.

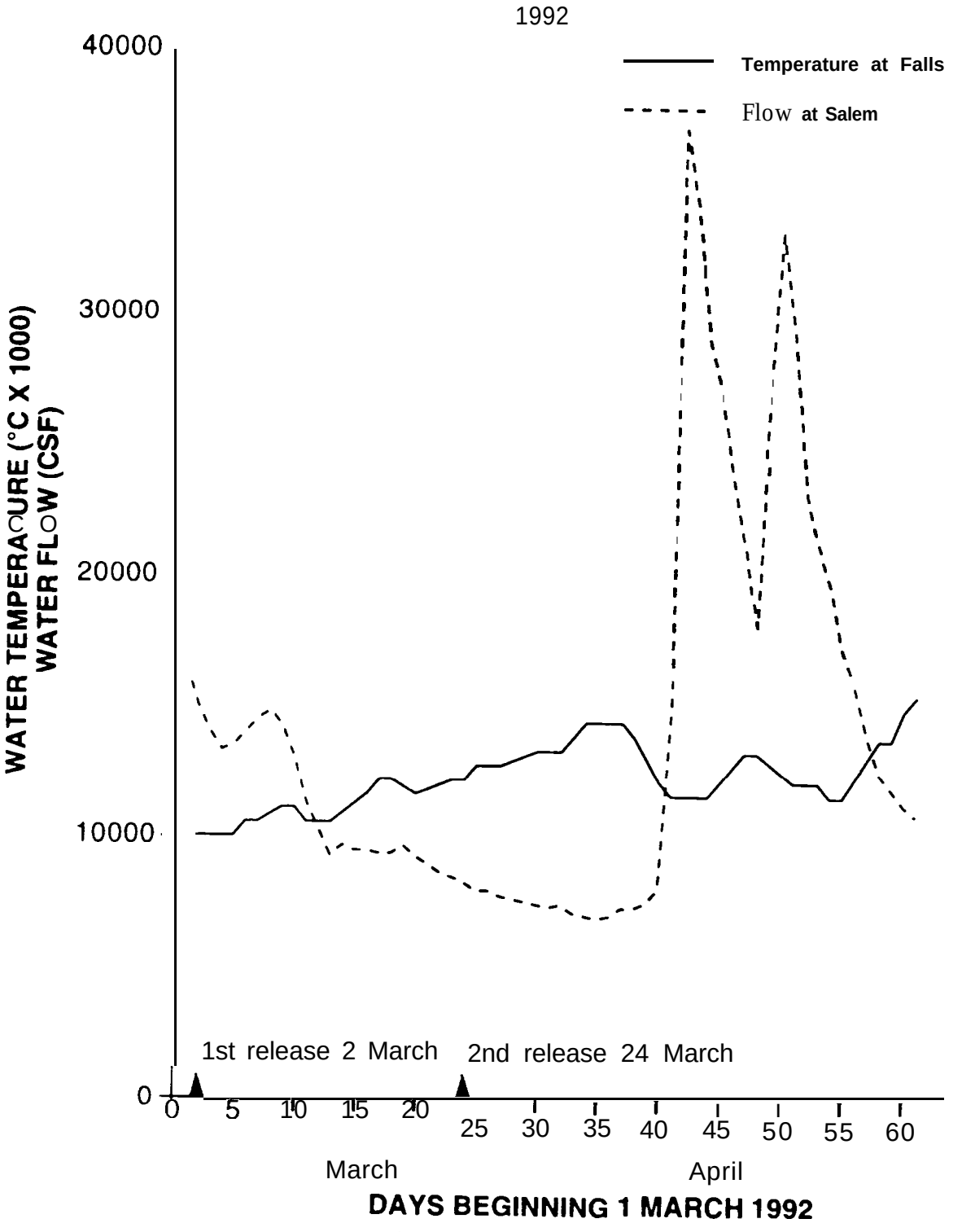


Figure 3 I. Water temperatures and flow rates describing the Willamette River during outmigration of radio-tagged juvenile spring chinook salmon in 1992. Water temperatures recorded at Willamette Ralls (RKM 43) provided by ODFW; water flows recorded at Salem (RKM 135) provided by the US Geological Survey.

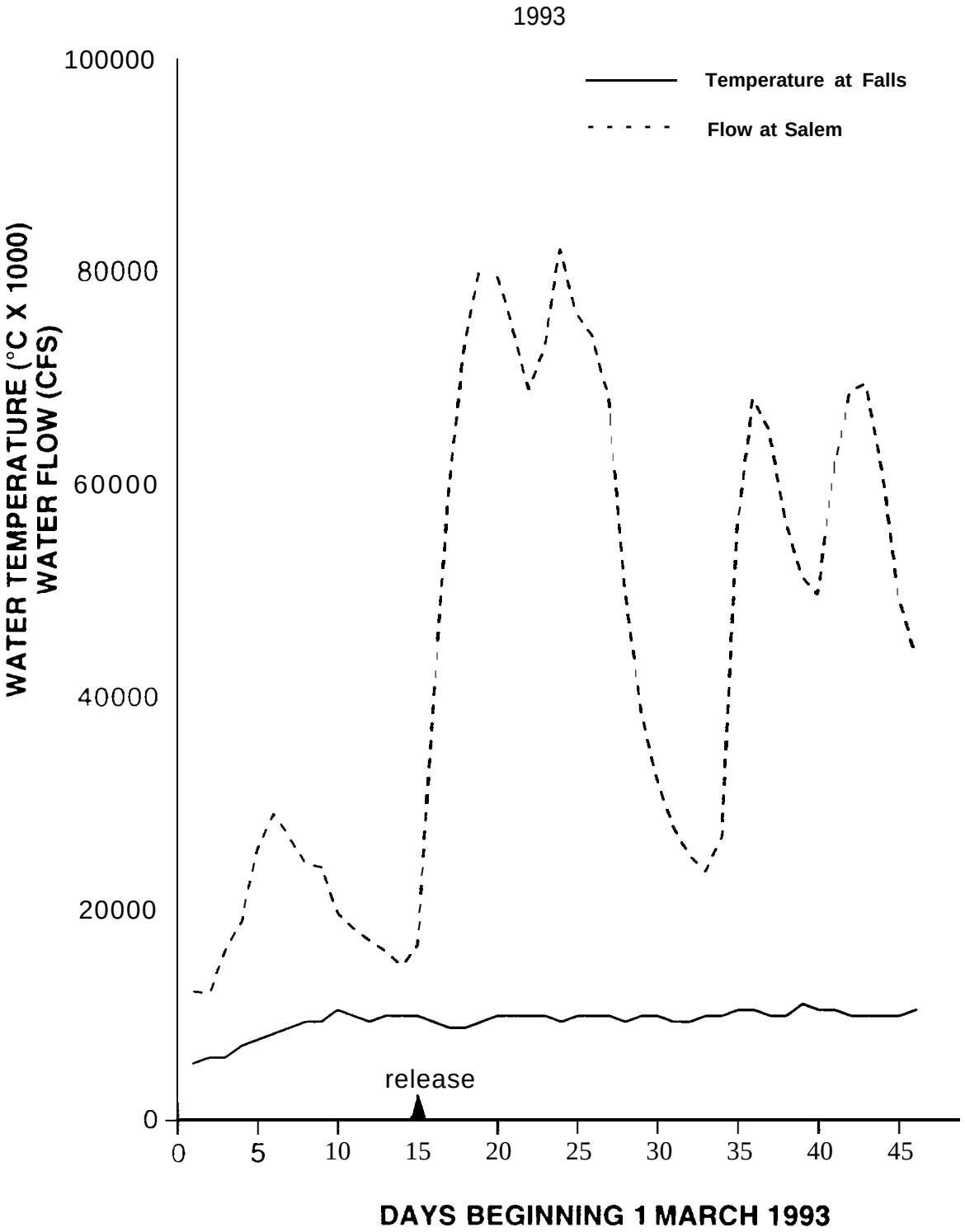


Figure 32. Water temperatures and flow rates describing the Willamette River during outmigration of radio-tagged juvanile spring chinook salmon in 1993. Water temperatures recorded at Willamette Ralls (RKM 43) provided by ODFW; water flows recorded at Salem (RKM 135) prov ided by the US Geological Survey.

reach of river between these areas speeds of between 4.5 and 5.5 km/h were measured, with the peak at Marshall Island.

1991 was the first year we measured current flow at selected locations in the river. The initial speed of smolts was 4 km/h, which slowed to 2.5 km/h between Clearwater Access and Beltline Bridge. The peak speed of nearly 5 km/h was achieved between Beltline and Harrisburg, and nearly the same speed was maintained to Wheatland Ferry. At Wilsonville outmigration speed declined to 2.5 km/h. We measured river velocities corresponding to these locations as the same as or 33% slower than the fish, except at Wheatland and below were they were 33 to 50% faster than the fish.

The number of fish with functioning transmitters for the first release in 1992 was small. The general patterns of fish movement measured in 1989 and 1990 were repeated though, with slower fish velocities high and low in the basin, and more rapid movement in the middle. Observed fish velocities were 33 to 50% of the measured river velocities, which tended to mirror the pattern of lower speed high and low in the basin. We have more complete data on fish released later on 15 March. They outmigrated at about 1 km/h as far downstream as the Santiam River confluence, increased to 2 km/h to Wheatland Ferry, then slowed to about 1.5 km/h at Newberg. Except for the Newberg reach these fish moved 33 to 50% slower than the river velocity we measured.

Our most complete data set is for 1993. Smolts outmigrated at about 3.5 km/h down to Marshall Island, then increased their speed to nearly 5 km/h to Corvallis. They maintained a speed in excess of 4 km/h to Newberg, then slowed to just above 2 km/h for the remainder of their journey to Willamette Falls. Except for the reaches to Marshall Island (where they migrated at river velocity) smolts migrated 33% faster than the river velocities we measured.

Recapture of Outmigrant Juveniles Between Release and Willamette Falls

In 1989, lacking a smolt trap at Willamette Falls, we experimented with several methods of recapturing Willamette Hatchery outmigrant smolts in the river above Willamette Falls. Our only success came from a beach seine in the area of Peach Cove (RKM 51). We decided to concentrate our efforts there in 1990.

The results of our efforts in 1990 to recapture juvenile spring chinook salmon representing the Willamette Hatchery production releases out of Dexter Pond are listed in Table 2. We were able to capture fish in first increasing and then decreasing numbers at times after release when (based on our radio telemetry data) it would be reasonable to expect juvenile spring chinook salmon to be present. Large numbers of juvenile spring chinook smolts were also

Table 2. Number of fish captured by beach seining at Peach Cove (River kilometer 51) to re-capture out-migrant spring chinook salmon released from Dexter Pond (River kilometer 324) on 7 March 1990.

Date	Days Post-Release	# Sets	# Fish	# Fin-Clipped
03/10/90	3	5	1 (wild?)	0
03/14	7	5	32	3
03/18	10	5	478	25
03/21	14	5	0	
03/24	17	5	0	
03/27	20	5	0	
03/30	23	5	0	

released this year from the McKenzie River Salmon Hatchery and the North Santiam Hatchery at Minto coincident with the Dexter releases, so it is likely that more that one stock is represented in our data. On any given day when fish were caught, the catches were very sporadic, i.e., most of the fish would be taken in a single seine haul, while the sets before and after would bring up few or no fish.

In 1991 we again seined at Peach Cove as well as electroshocked areas further upstream (Table 3). We collected hatchery fish with adipose clips and saved their heads for CWT analysis. These data (Fig 33) show that more than one stock is represented in our data. While a few hatchery fish were collected 8 days after release (including one fish from the standard treatment), most smolts were collected 15 days after the ODFW releases at Pengra Access; and fish from third Michigan treatments were not collected until 22 days after release. Our radio-tagged sample of fish first arrived at Willamette Falls four days after release, suggesting that our beach seining efforts may have been too late to encounter the majority of the hatchery smolts. Our sampling procedure could also have been affected by the previous flood conditions, the steadily falling river level, or both.

In 1992 our efforts to recapture juvenile spring chinook salmon representing Willamette Hatchery production released at Pengra Access on 2-3 March produced over 700 fish from the Downstream Migrant Bypass System at the PGE Sullivan Plant (Willamette Falls) and a few fish from several electroshocking expeditions during this time (Table 4). A much smaller sample of fish was obtained later from several upriver locations, collected by electroshocking (Table 5). Large numbers of juvenile spring chinook were also released by the McKenzie River Hatchery and hatcheries on the North and South Santiams (Marion Forks, Minto and Foster) coincident with the Pengra release (Table 6). The first radio-tagged smolts arrived at Willamette Falls on 8 March, 6 days after release) (Figures 15-17). Data collected by PGE biologists from the Sullivan trap (Figure 34) shows the pulse of large numbers of smolts between 6 and 7 March (days four and five after release); in fact we were present at midnight on 6 March when these fish arrived. By 10 March (eight days after release) PGE biologists trapped 40,000 smolts per day; with low total river flow a large percentage of the total flow was entering the Sullivan forebay. Furthermore, we began collecting adipose clipped (and therefore CWT identified) smolts on 7 March (five days after release) (Figure 35). Thus our small sample of radio-marked smolts first arrived at Willamette Falls at the same time as their unmarked siblings, an important validation of our telemetry data. Figure 35 does not show consistent differences in arrival of smolts from the three treatment groups, although there were gradually declining numbers of smolts reared in standard treatments, and uniform numbers of those reared in the third Michigan treatment, for example. We collected 33 fish from the standard treatment, 43 fish from triple density and 23 fish from the third Michigan treatment. A chi-square test on the total numbers of each treatment group was

Table 3. Number of spring chinook salmon juveniles captured by various means as part of a qualitative survey conducted at selected sites in the Willamette River to establish the presence or absence of juveniles at various times after the release of production fish from Willamette Hatchery on 28 February 1991. Numbers do not necessarily represent fish available because we chose not to disturb or take more fish than necessary for qualitative measure

Date	Day Post Hatchery Release	Location	River KM	Capture Method	Fish (N) Captured	(N) CWT's
3/08/91	8	Peach Cove	52	Seine	13	6
3/13/91	13	Pengra Ramp	323	Shock	2	0
		Buena Vista	171	Shock	21	5
3/15/91	15	Peach Cove	52	Seine	289	60
		Bemert Landing	45	Shock	36	9
		Rock Island	48	Shock	46	10
3/18/91	18	Jasper to Island Park	307	Shock	1	0
3/20/91	20	Buena Vista	171	Shock	8	3
3/22/91	22	Peach Cove	52	Seine	138	26
		Rock Island	48	Shock	11	2
		Bemert Landing	45	Shock	90	10
3/28/91	28	Buena Vista	171	Shock	2	0
		Bemert Landing	45	Shock	87	13
		Rock Island	48	Shock	95	21
4/04/91	35	Buena Vista	171	Shock	1	0
		Bemert Landing	45	Shock	63	9
		Rock Island	48	Shock	40	5
4/11/91	42	Buena Vista	171	Shock	2	1
		Bernert Landing	45	Shock	0	0
		Rock Island	48	Shock	1 (wild)	0
4/18/91	49	Buena Vista	171	Shock	11 (wild)	0
		Bernert Landing	45	Shock	0	0
		Rock Island	48	Shock	0	0

CWT's = coded wire tags

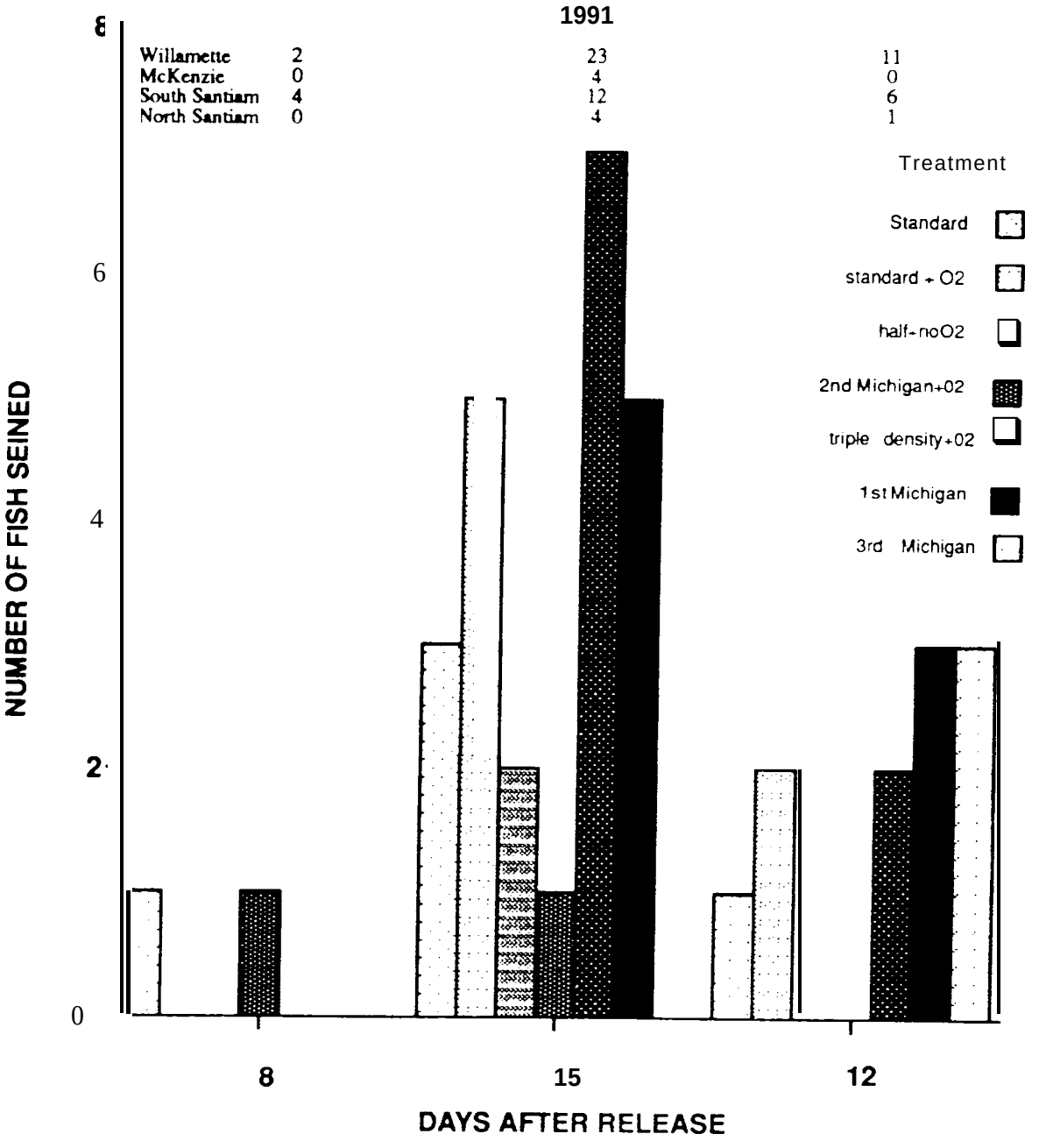


Figure 33. Analysis of coded wire tags from juvenile spring chinook salmon beach seined from Peach Cove area (Willamette RKM 52) during outmigration in 1991. Bar graph shows smolts from different treatment groups reared at Willamette Hatchery. Numbers above show hatchery release origin.

'Table 4. Summary of collections of Willamette Hatchery spring chinook Juveniles released on 2 March 1992, representing three treatments
Sullivan = fish trapped at PGE evaluator, Willamette Falls; electroshock = fish sampled by boat electroshocking

DATE COLLECTED	DAYS POST-RELEASE	LOCATION RECAPTURED	RIVER KM	CAPTURE METHOD	(N) FISH CAPTURED	NUMBER IN EACH TREATMENT		
						Standard	Triple Density	Third Michigan
7-Mar-92	5	Willamette Falls	43.0	Sullivan	9	4	3	2
8-Mar-92	6	Willamette Falls	43.0	Sullivan	5	1	3	1
9-Mar-92	7	Willamette Falls	43.0	Sullivan	7	1	5	1
1 O-Mar-92	8	Willamette Falls	43.0	Sullivan	2	1	1	0
12-Mar-92	10	Willamette Falls	43.0	Sullivan	10	3	4	3
13-Mar-92	11	Willamette Falls	43.0	Sullivan	3	1	2	0
15-Mar-92	13	Willamette Falls	43.0	Sullivan	7	3	3	1
16-Mar-92	14	Willamette Falls	43.0	Sullivan	6	3	2	1
18-Mar-92	16	Willamette Falls	43.0	Sullivan	4	0	3	1
18-Mar-92	16	Bemert	45.0	electroshock	2	0	2	0

DATE COLLECTED	DAYS POST-RELEASE	LOCATION RECAPTURED	RIVER KM	CAPTURE METHOD	(N) FISH CAPTURED	NUMBER IN EACH TREATMENT		
						Standard	Triple Density	Third Michigan
18-Mar-92	16	Rock Island	48.0	electroshock	5	2	2	1
1 g-Mar-92	17	Willamette Falls	43.0	Sullivan	3	1	1	1
21 -Mar-92	19	Willamette Falls	43.0	Sullivan	9	2	5	2
22-Mar-92	20	Willamette Falls	43.0	Sullivan	8	4	3	1
24-Mar-92	22	Willamette Falls	43.0	Sullivan	5	3	2	0
25-Mar-92	23	Willamette Falls	43.0	Sullivan	5	1	4	0
28-Mar-92	26	Willamette Falls	43.0	Sullivan	4	1	2	1
29-Mar-92	27	Willamette Falls	43.0	Sullivan	5	3	0	2
1-Apr-92	30	Willamette Falls	43.0	Sullivan	7	1	4	2
2-Apr-92	31	Willamette Falls	43.0	Sullivan	4	2	1	1
8-Apr-92	37	Willamette Falls	43.0	Sullivan	4	2	1	1
9-Apr-92	38	Willamette Falls	43.0	Sullivan	2	0	0	2
5-May-92	64	Pengra	323.0	electroshock	1	0	1	0

Table 5. Summary of collections by electroshocking at various sites along the Willamette River to establish the presence of slow migrating, residual, spring chinook salmon juveniles released 2 March 1992, Willamette Hatchery

DATE COLLECTED	DAYS POST-RELEASE	LOCATION	RIVER KILOMETER	(N) FISH CAPTURED	ADIPOSE CLIPPED	NOT MARKED
17-Mar-92	15	Pengra	323	9	5	4
		Clear-water	307	1	1	0
		Peoria	230	53	5	48
		Corvallis	216	2	2	
18-Mar-92	16	Santiam Junct.	174	0	0	0
		Buena Vista	171	1	1	0
		Rock Island	48	13	9	4
		Bemert	45	12	6	6
5-May-92	64	Pengra	323	1	1	0
		Clearwater	307	0	0	0
		Peoria	230	0	0	0
		Kiger Island	217	0	0	0
8-May-92	67	Buena Vista	171	0	0	0
		Rock Island	48	0	0	0
		Bemer t	45	0	0	0

Table 6. Oregon Department of Fish and Wildlife releases of juvenile spring chinook salmon in Willamette River Drainages, 1992.

RELEASE DATE	HATCHERY	RIVER STOCKED	NUMBER RELEASED	NUMBER CWT (%)
2-3 March	Willamette	Middle Fork Willamette	Total 790,000	297,000 (38%)
			40,000 Standard	33,000
			118,000 Triple Dense	33,000
			59,600 Third Michigan	33,000
	Dexter	Middle Fork Willamette	280,000	66,000 (24%)
2-6 March	Foster	South Santiam	340,0∞	112,000 33%)
4-5 March	Dexter	South Santiam	504,000	166,000 (33%)
5 March	Dexter	Molalla	67,000	unknown
6 March	Marion Forks/ Minto	North Santiam	560,000	unknown
12 March	McKenzie	McKenzie	750,000	

CWT = coded wire ags

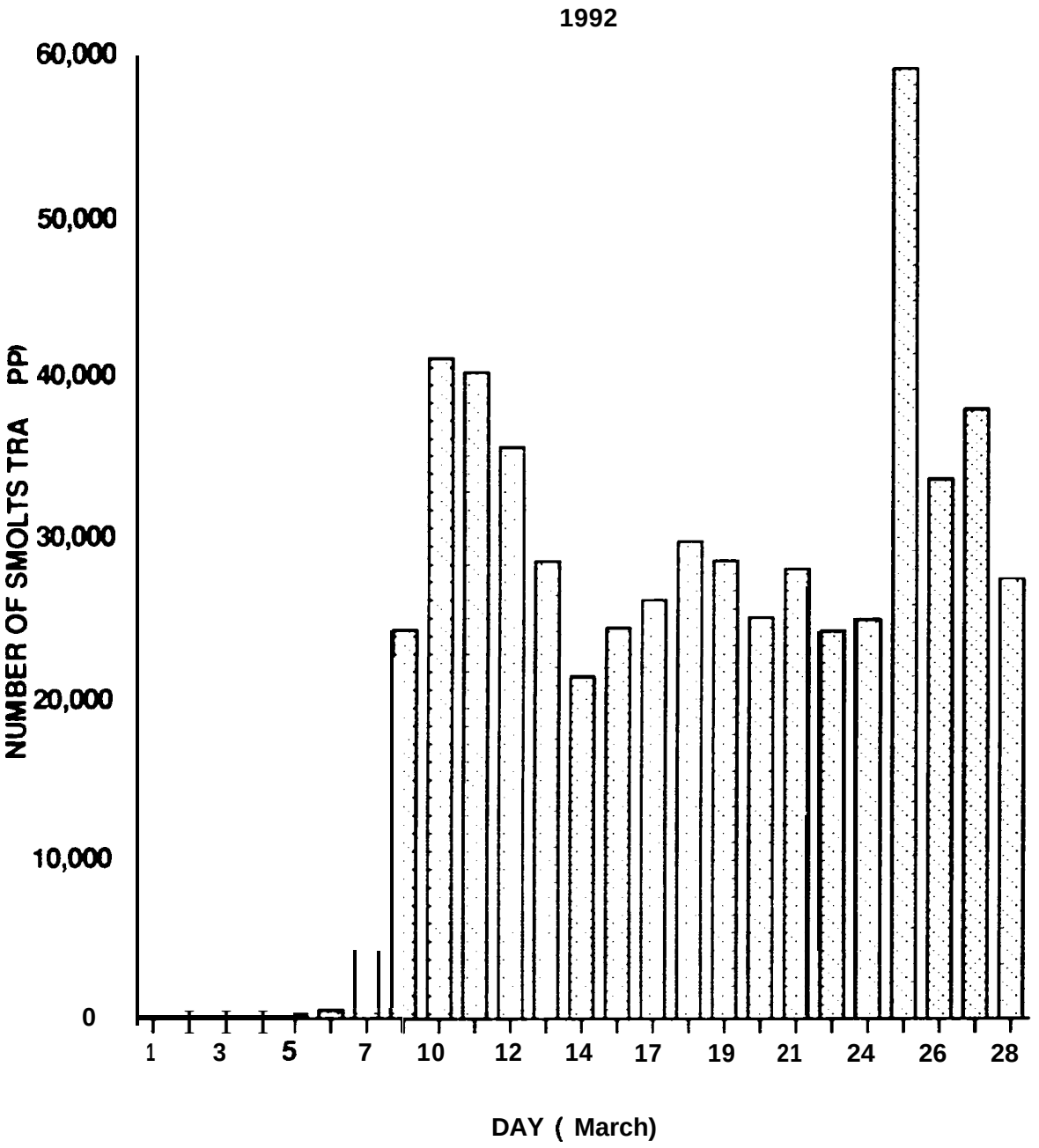


Figure 34. Counts of juvenile spring chinook salmon trapped by PGE personnel in the Sullivan Downstream Migrant Bypass System, Willamette Falls, 2-28 March 1992. Counts were made over eight to 24 hours, but standardized here for 24 hours. Wild smolts (identified by small size and sharpness of fins) comprised 25% of those trapped. Data courtesy of Don Clark, PGE.

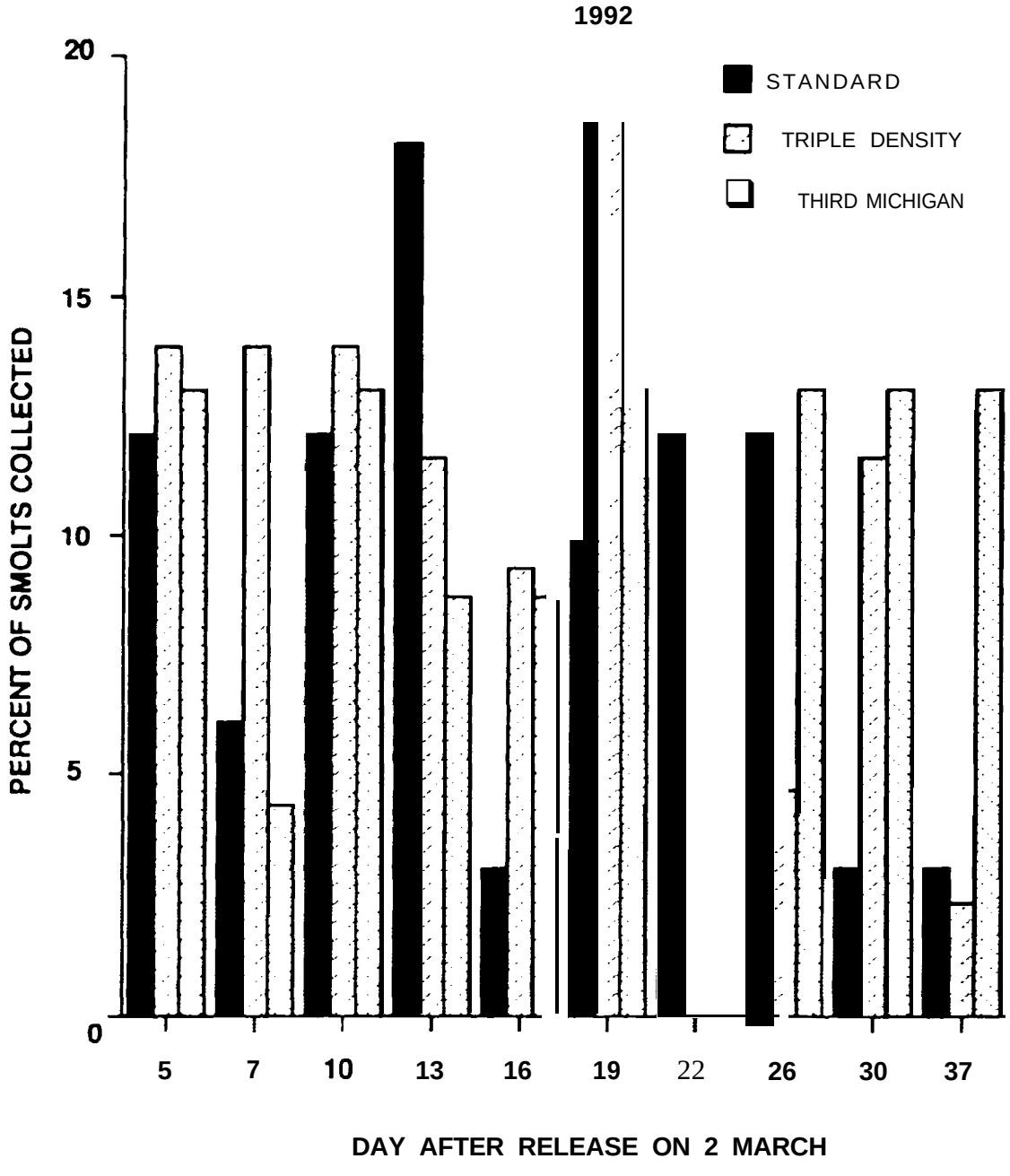


Figure 35. The frequency of adipose marked smolts from each of three treatment groups collected at the Sullivan Downstream Migrant Bypass System in 1992. Each group of three histogram bars represents smolts collected during one sampling period of **24** hours; the sum of 10 bars for each treatment equals 100% of the fish sampled for that treatment.

significant ($p < .05$). The same number of fish in each treatment were marked at the hatchery and released (Table 6).

In 1993 our efforts to recapture downstream representatives of the ODFW Willamette Hatchery releases at Pengra Access again were concentrated at the Sullivan trap at Willamette Falls. Collections of smolts by PGE biologists (Figure 36) showed a large increase between 15 and 16 March (less than 200 chinook smolts on 11/ 12 March rose to nearly 2,000 smolts on 15/16 March) and a peak (nearly 3,500 smolts) between 17 and 18 March. Arrival of our first radio-tagged fish is coincident with the increase in numbers counted on the 15/16th. We began sampling for CWT hatchery fish on 19 March, four days after the Pengra releases, and therefore missed the first wave of hatchery fish. Sampling until 24 days after release (Figure 37) we were able to collect 34 smolts from standard treatments, 31 triple density and 33 from the third Michigan treatment, a strikingly equal number of each treatment group and not statistically different. Their distribution in the sample is spread throughout our sampling efforts, with third Michigan fish being absent from the early and late sampling days.

Evaluation of Juvenile Spring **Chinook** "Residualism"

Juveniles Encountered. In 1990 we sampled for chinook smolts using electroshock and hook and line methods between March and June (Table 7). In general, juvenile spring chinook could be found in the upper, middle, and lower reaches of the Willamette River early in March and April, **but** could not be found later in May or June. It seems reasonable that most fish eventually moved out of the Willamette River system; therefore we did not find any evidence for true residuals. These data are consistent with our radio telemetry results. We recorded three radio-tagged fish in the vicinity of the release site for almost two weeks, and we were successful in capturing 11 smolt-sized spring chinook on 6 April, one month after a release of Willamette Hatchery production fish from Dexter Pond; two of these were adipose fin-clipped and with coded wire **tags** which revealed that these were from the 7 March Dexter release. We were particularly successful in capturing spring chinook smolts at the mouth of the Tualitan River (Willamette RKM 45) during March and early April. Again, our radio telemetry data indicated that some tagged fish ceased (at least temporarily) downstream migration just above Willamette Falls and remained in this **area for** up to 15 days after release.

In 1991 we electroshocked for spring chinook smolts in the upper **and** middle river, and at several lower river sites during March and April (Table 3). Based on the absence of juvenile spring chinook of hatchery origin in the middle and lower reaches of the Willamette River in late April, we discontinued sampling in May. These data are also consistent with our radio-telemetry findings. All of the radio-tagged juveniles moved away from the release area immediately. Two weeks after release, electro-shocking in the release site yielded

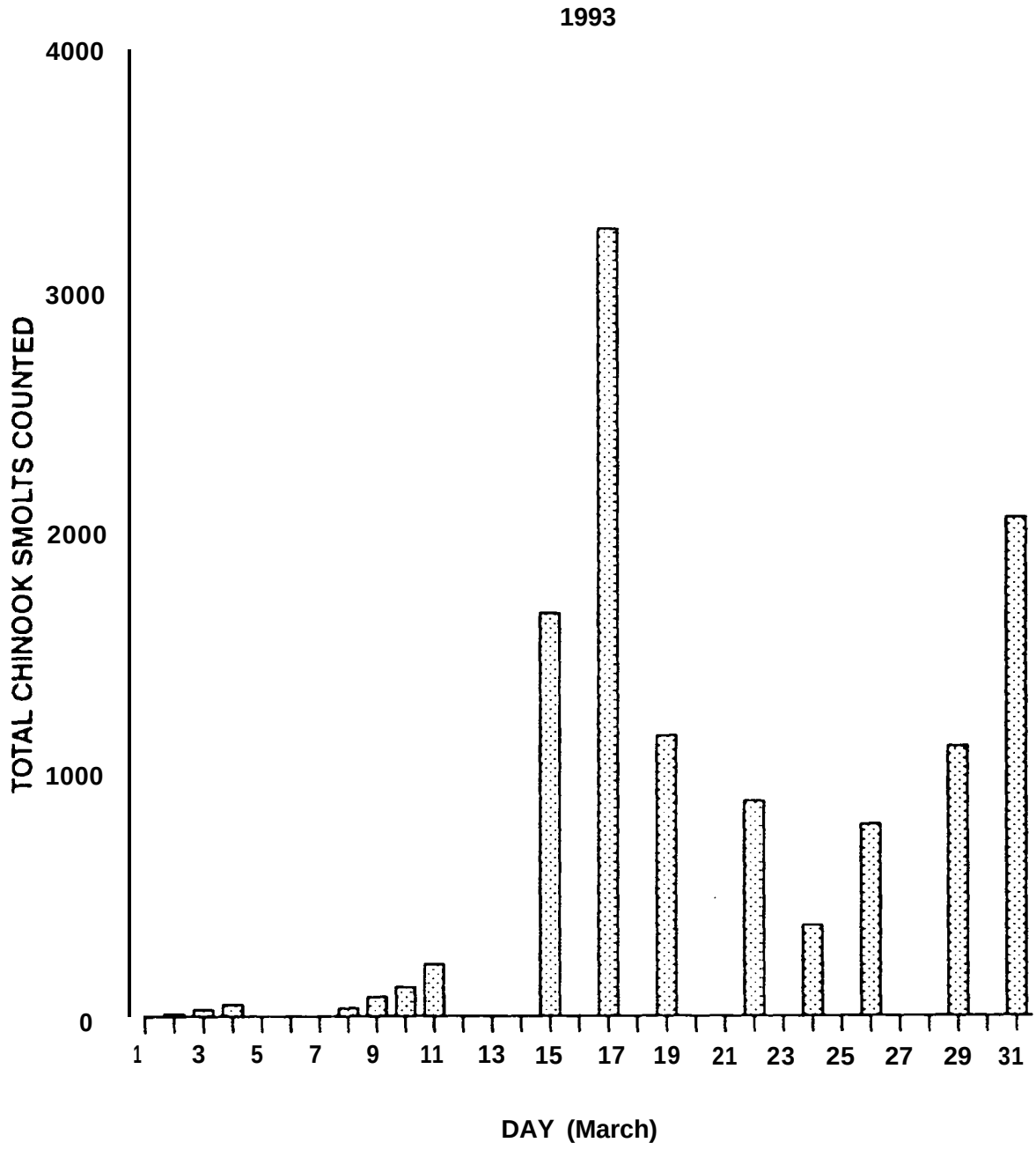


Figure 36 Counts of juvenile spring chinook salmon trapped by PGE biologists in the Sullivan Downstream Migrant Bypass System. Willamette Falls. during March 1993. Counts were made over 24 h periods but not for all days of the month. Data courtesy of Don Clark. PGE.

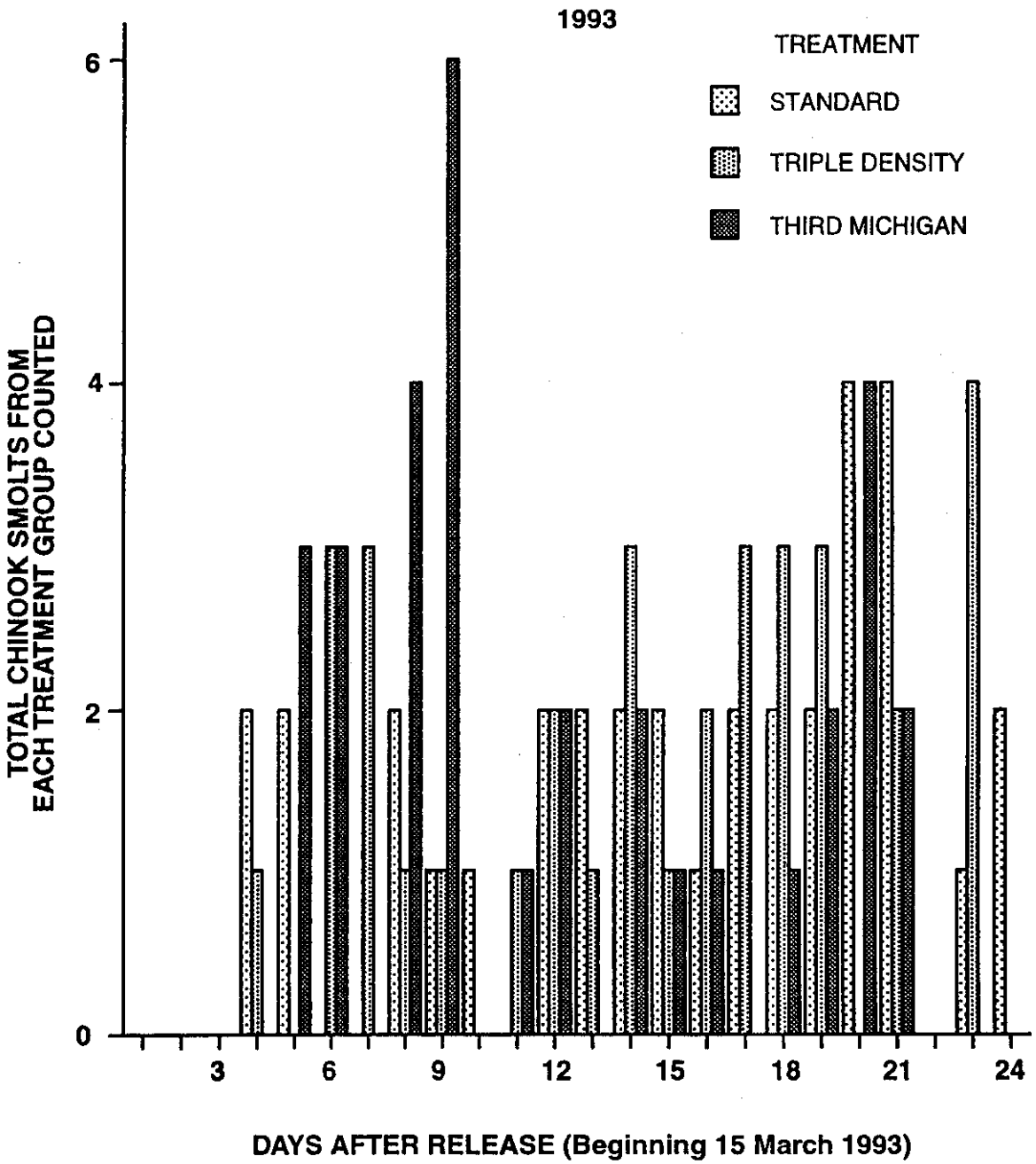


Figure 37. The frequency of smolts collected at the Sullivan Downstream Migrant Bypass Facility in 1993. Days represent two-day intervals when we collected from 1100 on day one to 0800 on day two. Numbers of smolts represent fish collected at all hours. N = 34 from standard treatment, 31 triple density, and 33 third Michigan treatment.

Table 7. Number of spring chinook salmon smolts captured by various means as part of a qualitative survey conducted at selected sites in the Willamette River to establish the presence or absence of juveniles at various times after the release of production fish from Willamette Hatchery in 990. Numbers do not necessarily represent fish available because we chose not to disturb or take more fish than necessary for qualitative measure.

Location			Gut Contents	
Date	(River KM)	Capture Method	cm^3 (x + SEM)	N
	UPPER RIVER:			
4 Apr	323	Hook-and-line	1.63 + 0.27	2
6 Apr	327	Electroshock	1.24 + 0.12	11
13 Jun	323	Electroshock	-------	0
	MIDDLE RIVER:			
3 Apr	232	Electroshock	1.50 + 0.12	3
9 Apr	251	Electroshock	0.96 + 0.29	6
10 Apr	174	Electroshock	2.08 + 0.57	6
11 Apr	240	Electroshock	1.13 + C.27	2
	LOWER RIVER:			
23 Mar	45	Hook-and-line	-------	17
27 Mar	45	Kook-and-line	3.73 + 0.11	16
30 Mar	45	Hook-and-line	1.10 + 0.07	12
5 Apr	45	Electroshock	1.68 + 0.14	22
12 Apr	45	Electroshock	1.45 + 0.09	20
18 Apr	45	Electroshock	1.20 + 0.11	5
17 May	45	Electroshock	-------	0
12 Jun	45	Electroshock	-------	0

no hatchery fish and only two wild juvenile spring chinook. Shocking in the same area one week later produced only one juvenile, again a wild fish. We were successful in capturing spring chinook smolts in the lower river through 4 May, although no radio-tagged fish lingered in the Willamette Falls area.

In 1992 we conducted electro-shocking sampling efforts in same areas as in previous years (in mid-March and early May, Table 5). In mid-March we shocked fewer fish than in previous years, the most (53) at Peoria in the middle river. We encountered no smolts in these areas in May. It is interesting that our sampling at Sullivan yielded two smolts, released near Dexter Ponds in August 1991, outmigrating with the spring releases. All of the radio-tagged juveniles moved away from the release site immediately. Two weeks after release, electro-shocking at the release site yielded five hatchery spring chinook smolts and four wild juveniles. Shocking in the same area the first week of May produced only one juvenile hatchery fish. These data are consistent with our radio-telemetry findings.

In 1993 we sampled by electro-shocking for six days, up to 38 days after release of the Willamette Hatchery smolts at Pengra (Table 8). We were singularly unsuccessful at capturing more than eight fish at any location, and on the 38th day after release no fish could be found even in the lower river site (mouth of the Tualitan River) which was most likely to produce fish. The high water in 1993 seemed to flush fish from the system quite rapidly.

Gill ATPase, a measure of smoltification or tendency to residualize. Na^+/K^+ gill ATPase activity data from fish sampled just prior to release from 1990 to 1993 are found in Figures 38-41. These values provide a basis upon which to compare samples collected downriver. In 1990 we collected gill samples from standard production smolts just prior to release and just after release, with means of 21.9 ± 1.2 and 18.5 ± 1.6 μmol Pi/mg protein/hr respectively. From 1991 to 1993 we collected gill samples from fish in each of the three treatments. Analysis of variance for 1991 suggests that there were significant differences between fish reared in the three treatments. Pair-wise comparisons using Duncan's new multiple range and Fisher (PLSD) tests at the 95% confidence level demonstrated significant differences as follows: fish from the triple density treatment had levels of ATPase activity significantly higher than those from the third Michigan treatment (8.4 ± .296 vs 7.1 ± .222 μmol Pi/mg protein/hr), as did fish from the standard density treatment (7.96 ± .369 μmol Pi/mg protein/hr). In 1992 gill ATPase activity from smolts in the third Michigan treatment (5.6 ± .52 μmol Pi/mg protein/hr) was significantly lower than fish from standard and triple density treatments (9.04 ± 1.17 and 8.63 ± 1.04 μmol Pi/mg protein/hr, respectively). In 1993 there were no significant differences in gill ATPase activity among any of the three treatments: standard 6.5 ± .36 μmol Pi/mg protein/hr, triple density 6.07 ± .35 μmol Pi/mg protein/hr, and third Michigan 5.85 ± .31 μmol Pi/mg protein/hr.

Table 8. Summary of collections by electroshocking at various sites along the Willamette River to establish the presence of slow migrating, or residual, spring chinook salmon juveniles in 1993.

DATE COLLECTED	DAYS POST-RELEASE	LOCATION	RIVER KM	(N) FISH CAPTURED	ADIPOSE CLIPPED	NOT MARKED
23-Mar-93	8	Corvallis	83	8	5	3
		Jasper	314	1		1
		Coberg	280	0		
6-Apr-93	22	Tuali tan	45	6		6
		Coalca	48	2		
		Buena Vista	171	0		
8-Apr-93	24	Pengra Ramp	323	0		
		Clearwa ter	307	0		
13-Apr-93	29	Buena Vista	171	0		
		Coalca	48	0		
		Tuali tan	45	6		
20-Apr-93	36	Pengra Ramp	323	0		
		Clearwater	307	1		
		Corvallis	83	2		
22-Apr-93	38	Buena Vista	171	0		
		Coalca	48	0		
		Tuali tan	45	0		

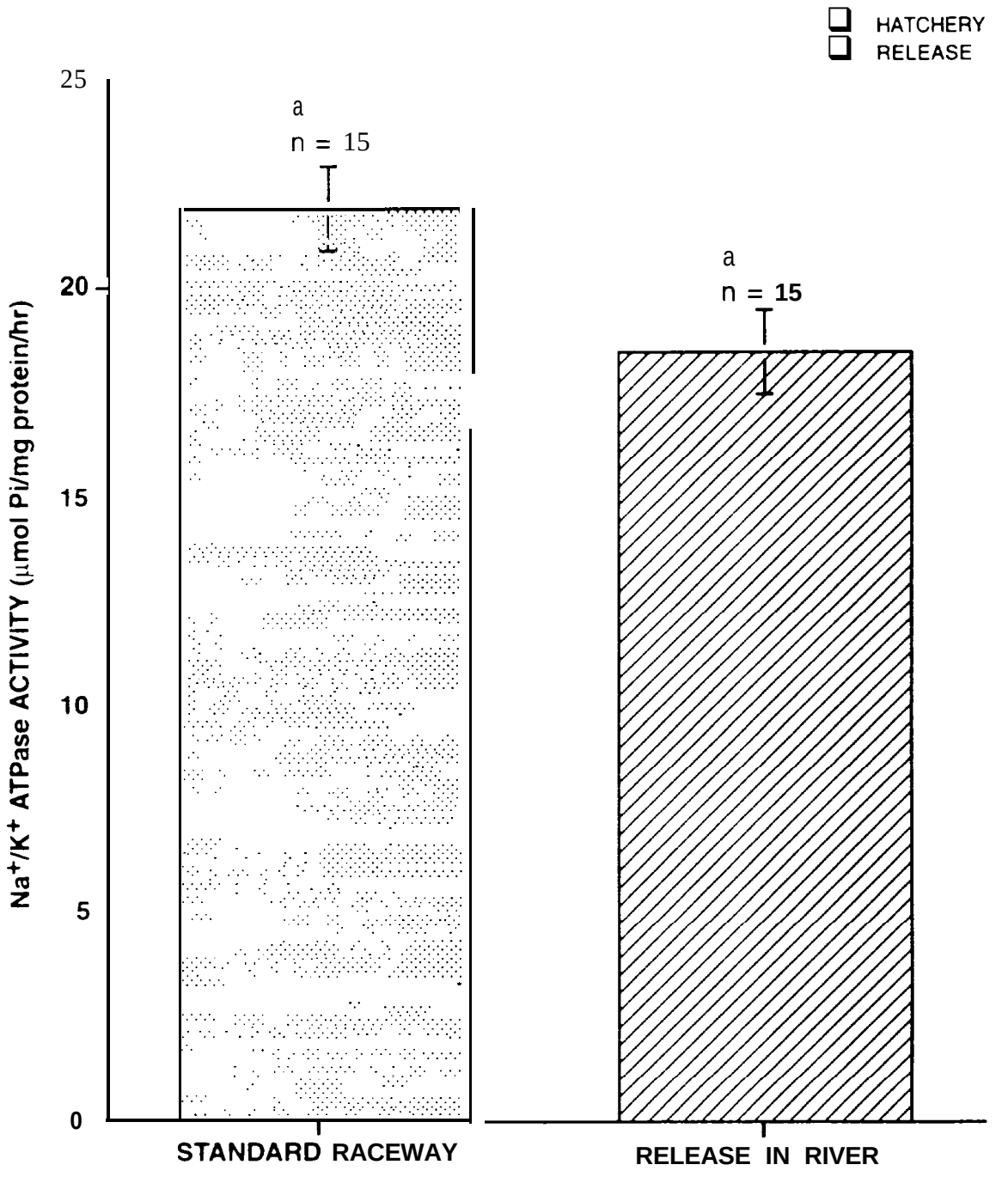


Figure 38 Na+/K+ ATPase in the gills of juvenile spring chinook salmon (Willamette Hatchery, 1989 brood-year) immediately before and after release on 12 March 1990. Bars indicate the mean ± SE: Duncan's New Multiple Range Test showed means labeled with different letter to be statistically different ($p < 0.05$).

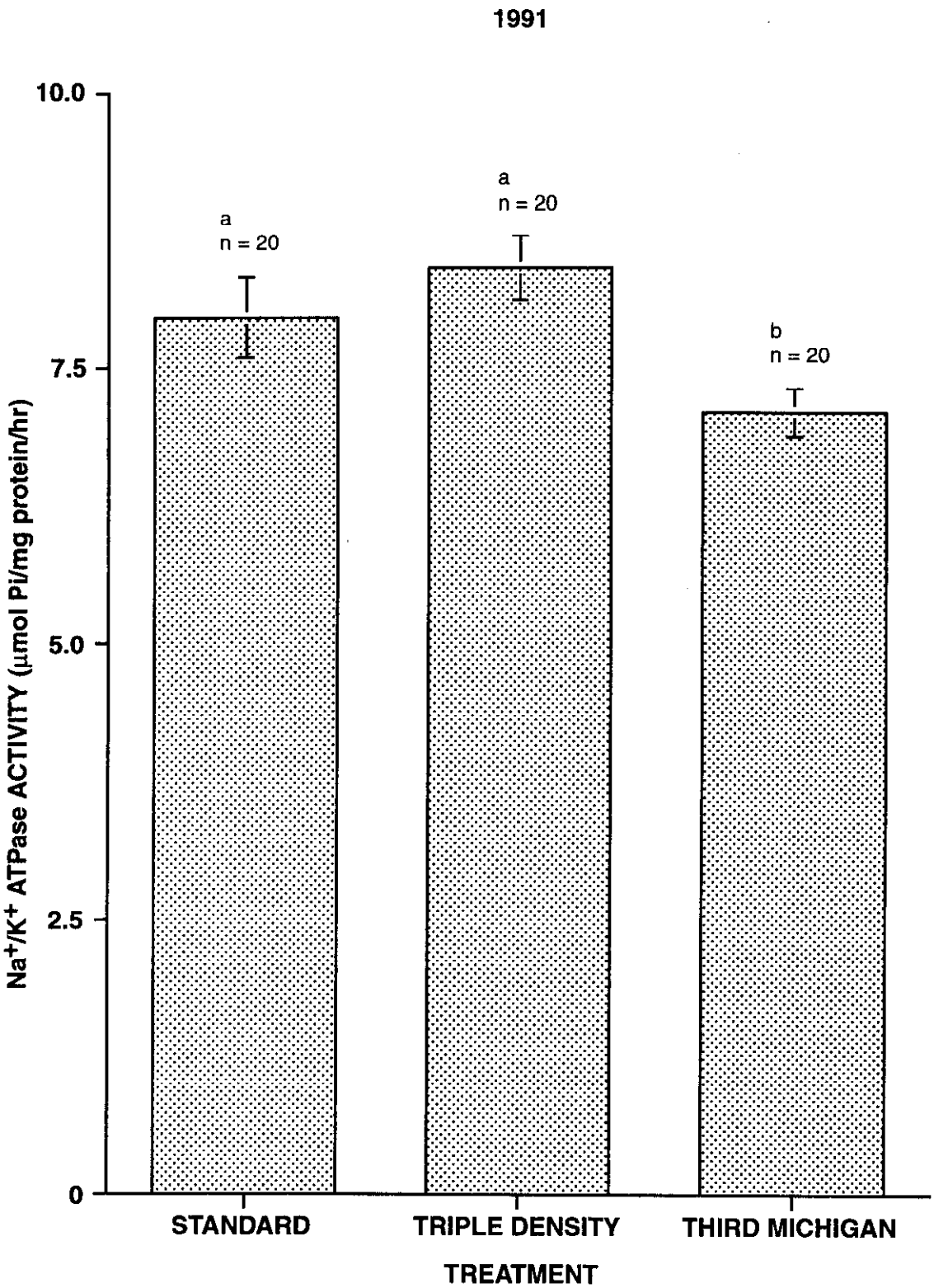


Figure 39. Na^+/K^+ ATPase in the gills of juvenile spring chinook salmon reared under three different treatments (Willamette Hatchery, 1990 brood-year) immediately before release on 1 March 1991. Bars indicate the mean + SE; Duncan's New Multiple Range Test showed means labeled with different letters to be statistically different ($p < 0.05$).

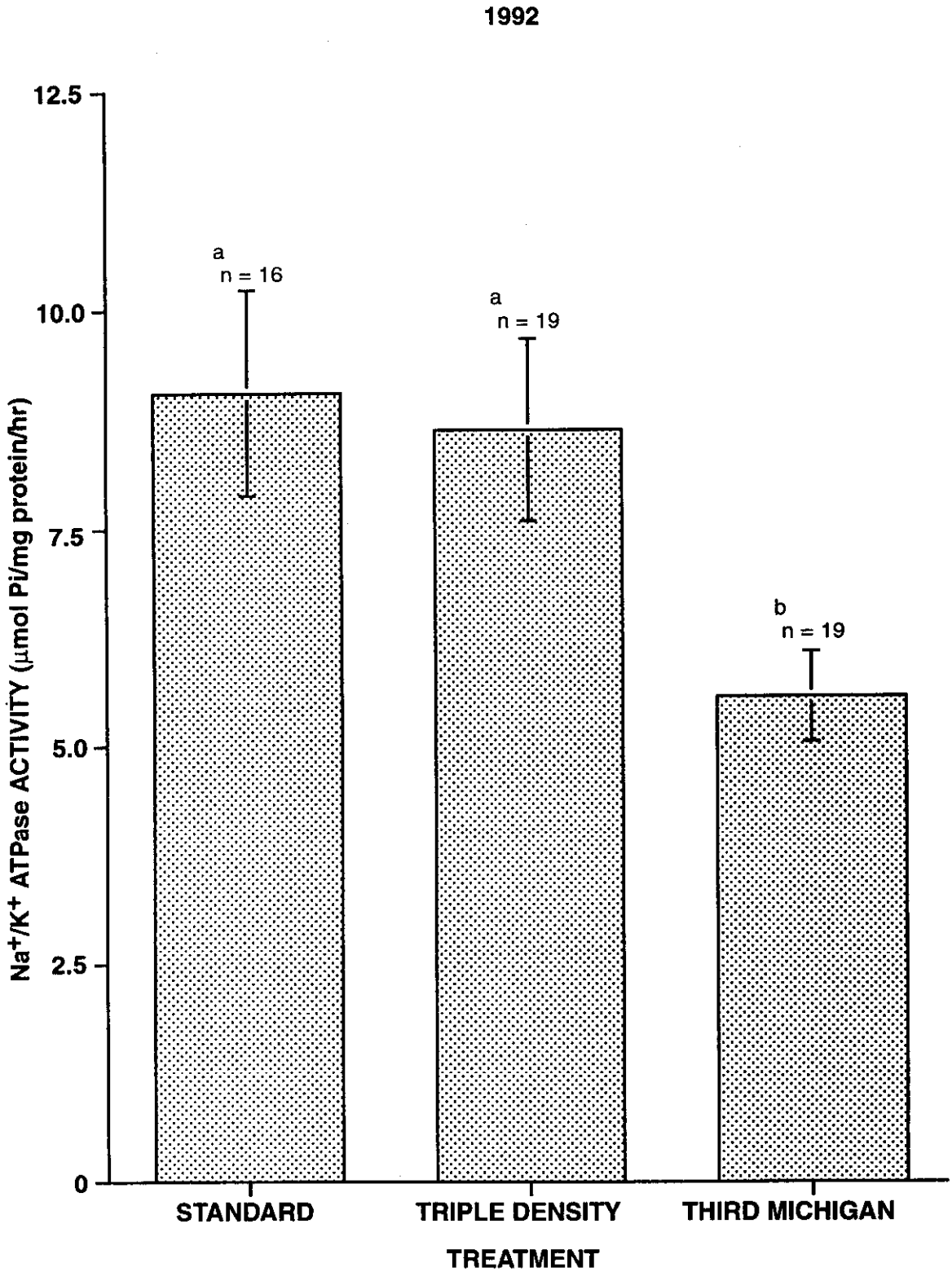


Figure 40. Na^+/K^+ ATPase in the gills of juvenile spring chinook salmon reared under three different treatments (Willamette Hatchery, 1991 brood-year) immediately before release on 2 March 1992. Bars indicate the mean + SE; Duncan's New Multiple Range Test showed means labeled with different letters to be statistically different ($p < 0.05$).

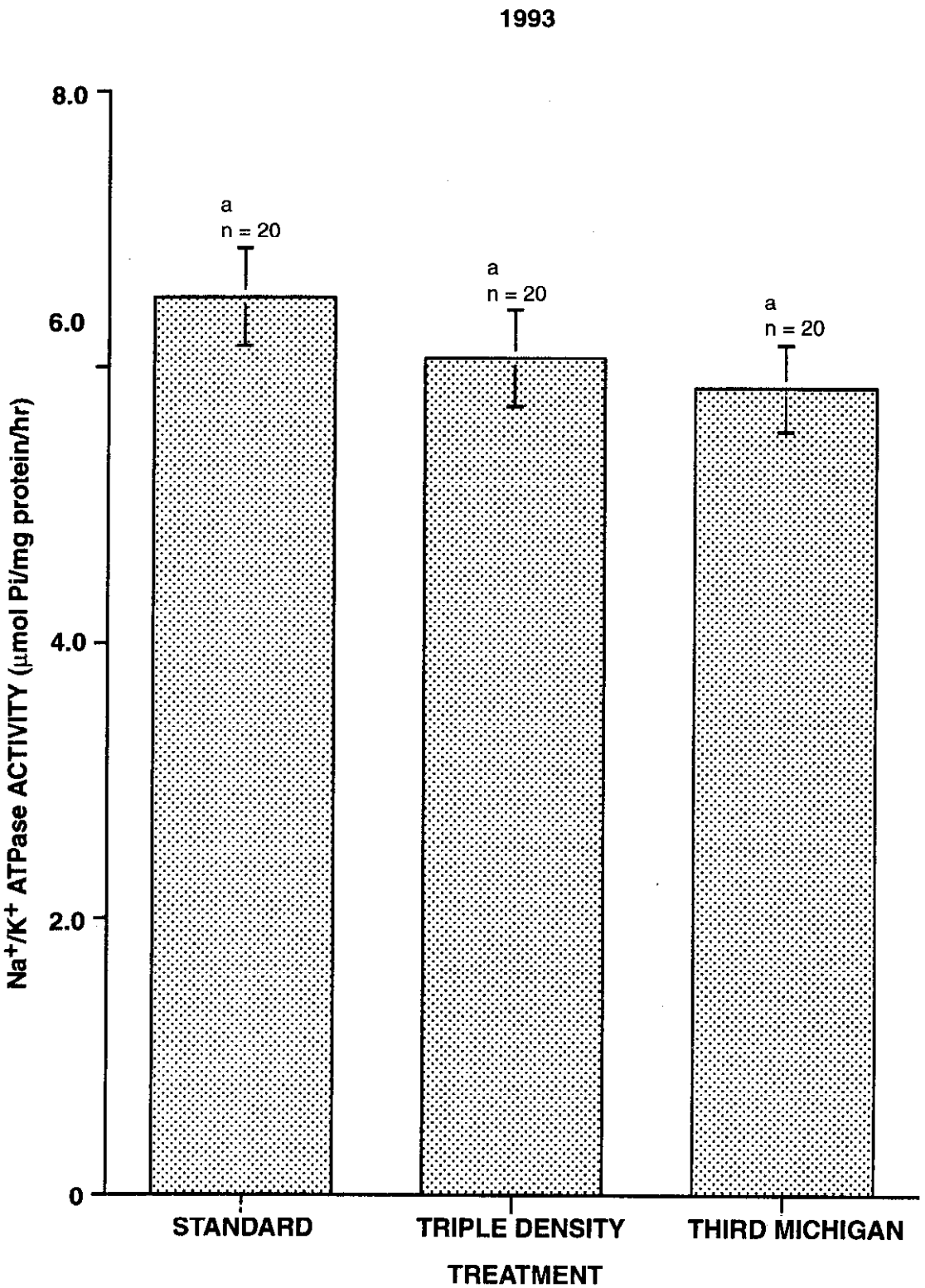


Figure 41. Na^+/K^+ ATPase in the gills of juvenile spring chinook salmon reared under three different treatments (Willamette Hatchery, 1992 brood-year) immediately before release on 15 March 1993. Bars indicate the mean + SE; Duncan's New Multiple Range Test showed means labeled with different letters to be statistically different ($p < 0.05$).

In 1990 we analyzed gill ATPase activities for juveniles collected during March and April (pre-release, post-release, beach-seined, and electroshocked) at various sites (Table 9). These data were subjected to analysis of variance and, where significant between-group differences were found, pairwise comparisons were carried out using Duncan's multiple range test. With the exception of fish sampled at the time of release (immediately post-transport) and those sampled from the middle river, all other groups were found to be statistically different from the Willamette Hatchery (pre-release) sample ($p < 0.05$). Juvenile spring chinook sampled from the lower river (i.e., just above Willamette Falls) four to six weeks following release of Willamette Hatchery production fish had significantly elevated gill ATPase activities compared to hatchery fish. In contrast, juveniles collected from the upper river (i.e., within 10 km of the release site) four weeks post-release had significantly depressed gill ATPase activities. Similarly, juveniles collected from the lower river one to two weeks post-release also had low-er gill ATPase activities than hatchery fish.

In 1991 we performed analysis of variance on gill ATPase in smolts before release from Willamette Hatchery and from similarly treated fish collected in the river from 6-35 days after release. There were no significant differences between treatments (aside from the lowered ATPase in fish from third Michigan treatments reported above), but there was a highly significant ($p < .0001$) elevation (more then doubling) of gill ATPase activity in fish 20 days and more after release. Figure 42 compares fish reared under standard conditions to illustrate the differences in ATPase activity. ATPase activity levels in juveniles reared under standard conditions in the hatchery and at several post-release sampling locations (RKM 323, 174, 48, and 44) were also significantly ($p< .0001$) elevated the farther downriver juveniles were collected.

Fork length (size) of juveniles reared under standard conditions in the hatchery and those sampled from the river compared with gill ATPase activity, showed a negative correlation coefficient of –0.278. The regression ANOVA which is significant at the .05 level suggests that in our sample larger fish have the lowest enzyme activity.

In 1992 our prerelease hatchery samples are compared with a small ($n=10$) sample of fish representing all treatments from Willamette Hatchery electroshocked 5 km above Willamette Falls, and a much larger sample ($n = 238$) collected up to 40 days after release at the Sullivan evaluator (Figure 43). Again, hatchery fish had ATPase values averaging 7.8 µmol Pi/mg protein/hr and fish electro-shocked from the river at about 16 days after release had 9.9 µmol Pi/mg protein/hr. Gill ATPase steadily increased then decreased in the fish collected over the run within 10 km of Willamette Falls, from 5.34 µmol Pi/mg protein/hr 5-8 days after release to 12.7 µmol Pi/mg protein/hr 29-32 days after release; subsequently sampled fish (33-40 days) showed a decreased level of about 8 µmol Pi/mg protein/hr.

Table 9: Gill ATPase activity (μmoles Pi/mg protein/hour; mean + S.E.) in juvenile spring chinook salmon. Days after release and kilometers from release calculated based on release of Willamette Hatchery production out of Dexter Pond (RM 327) on 7 March 1990.

Sample Site	Kilometers From Release	Collection Date	Days After Release	ATPase Activity + SE	N
Willamette Hatchery	-----	12 March	-----	21.9 + 1.2	15
Post-Transport (Pengra Ramp)	-----	12 March	-----	18.5 + 1.6	15
Peach Cove	275	14 March	7	12.7 + 0.7*	20
Peach Cove	275	18 March	11	13.7 + 0.8*	20
Peach Cove	275	21 March	14	14.8 + 0.8*	8
Upper River	10	6 April	30	12.1 + 1.0*	11
Middle River (Harrisburg)	66	9 April	33	24.9 + 2.2	6
Middle River (Buena Vista)	156	10 April	34	24.4 + 1.3	6
Lower River (Tualatin)	282	5 April	29	28.4 + 1.2*	20
Lower River (Tualatin)	282	12 April	36	31.3 + 1.9*	20
Lower River (Tualatin)	282	18 April	42	29.4 + 3.8*	5

*Significantly different from Hatchery samples; $p < 0.05$.

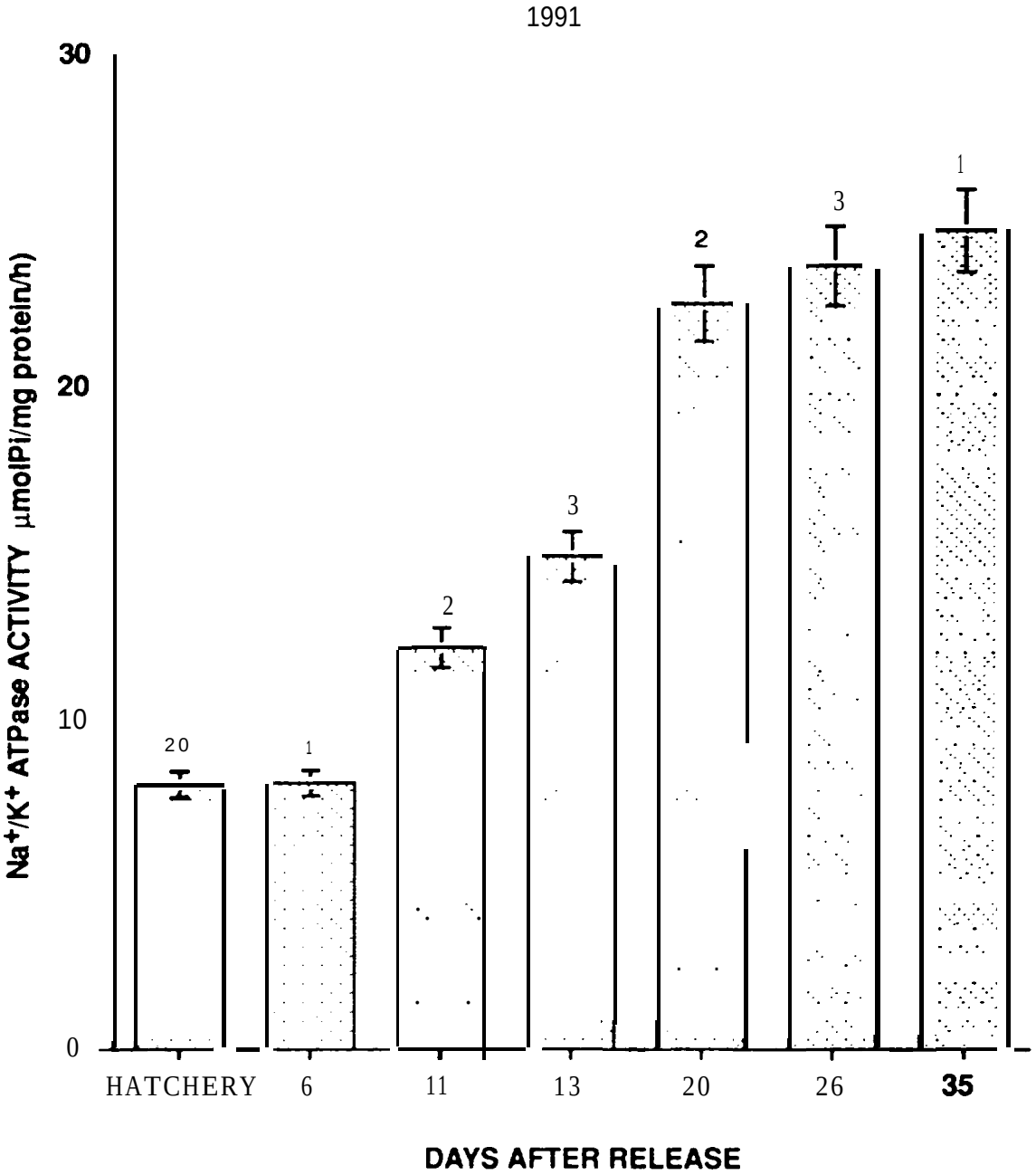


Figure 42. Na^+/K^+ ATPase in the gills of juvenile spring chinook salmon (Willamette Hatchery, 1990 brood-year) reared under standard density with no oxygen supplementation and released in 1991. Twenty samples were taken in the hatchery pre-release (day 1); the remaining samples were collected by beach seining or electro-shocking areas of the Willamette River above Willamette Falls. Number of fish above standard error bars.

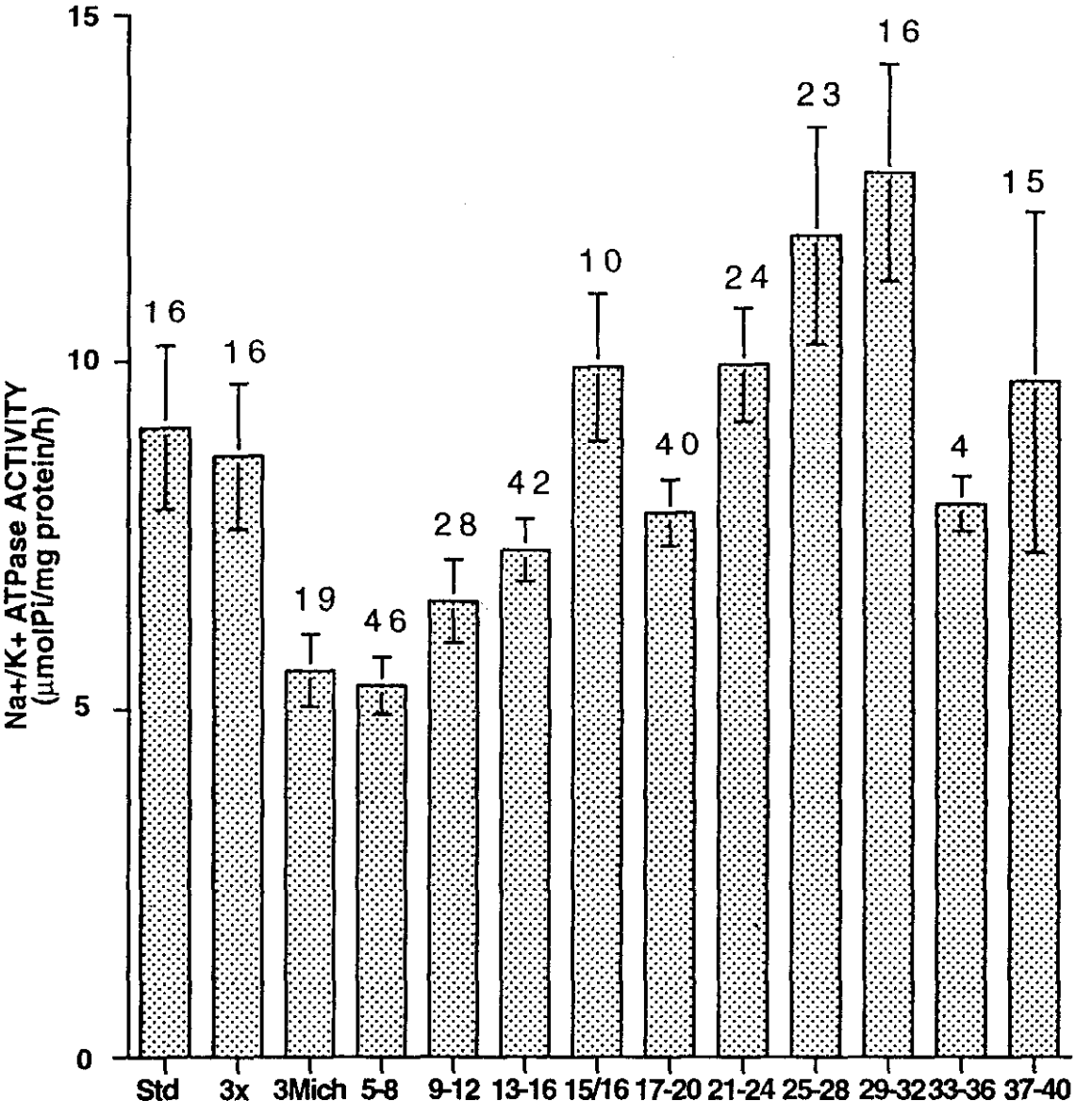


Figure 43. Comparison of Na+K+ ATPase in the gills of juvenile spring chinook salmon (Willamette Hatchery, 1991 brood-year) from several locations and times after release in 1992. From left, first three bars represent hatchery values for indicate treatment; other bars represent values for indicated treatment; other bars represent values (except "15/16" from RKM 45 electroshocking) from Sullivan trap collections. Number of fish below standard error bars (see text).

In 1993 we collected a robust sample of 94 fish from the three study treatments sampled at the Sullivan plant up to 25 days after release with which to compare hatchery ATPase values (Figure 44). The treatments were pooled after performing an ANOVA which showed no significant interaction. The dominant pattern was an increase in ATPase activity, from a mean of 6.1 µmol Pi/mg protein/hr in the hatchery to 15.8 µmol Pi/mg protein/hr 21-25 days after release. Values are significantly different throughout, with the exception of the 1-5 d and 6-10 d time periods, and the 16-20 d and 21-25 d time periods. Again there was a gradual negative correlation between length and ATPase activity, significant only between the 14-15 and 16-17cm size classes.

Evaluation of Outmigrant Juvenile Spring Chinook Food Habits.

In 1990 and 1991 all of the fish we examined were collected by seining or electroshocking. In 1992 and 1993, 95% of the fish were collected at the Sullivan evaluator, and how long they were in the raceway there is unknown. In 1990 only three of 105 fish had empty guts. A qualitative assessment of gut contents revealed that fish were feeding primarily on aquatic insects; flies (dipterans), mayflies, beetles, stoneflies, bees, ants, and caddisflies were the food items most commonly encountered (Figure 45).

Of the 214 fish examined in 1991 all but one had food in the gut. A qualitative assessment of gut contents revealed that fish were feeding primarily on aquatic insects; stoneflies (Plecoptera), true flies (Diptera), Caddisflies (Tricoptera), amphipods, beetles (Coleoptera) and bees/ants (Hymenoptera) were the most common food items (Figure 46).

From over 600 fish examined in 1992 only $4 had identifiable food in their guts. While electrical failure of a freezer caused degeneration of a significant portion of our sample and the residence time of smolts in the Sullivan trap (where there would be little or no food) is long enough for fish to digest much in their gut contents, we are convinced that outmigrating fish were feeding as in previous years. Qualitative assessment of gut contents revealed that smolts were feeding primarily on aquatic insects; true flies (Diptera), caddisflies (Tricoptera), bees and ants (Hymenoptera), and mayflies (Ephemoptera) were the most common food items (Figure 47). By contrast, in 1991 the most common items were bees/ants (Hymenoptera), true flies (Diptera), caddisflies (Tricoptera), amphipods, mayflies (Ephemoptera), and beetles (Coleoptera).

In 1993 all but 25 of 251 stomachs examined contained food (Figure 48). The most prevalent contents were unidentified insect and organic matter (63%), followed by Plecoptera (11.5%), Trichoptera (11.2%), Diptera (4.9%) and plant matter (4.3%).

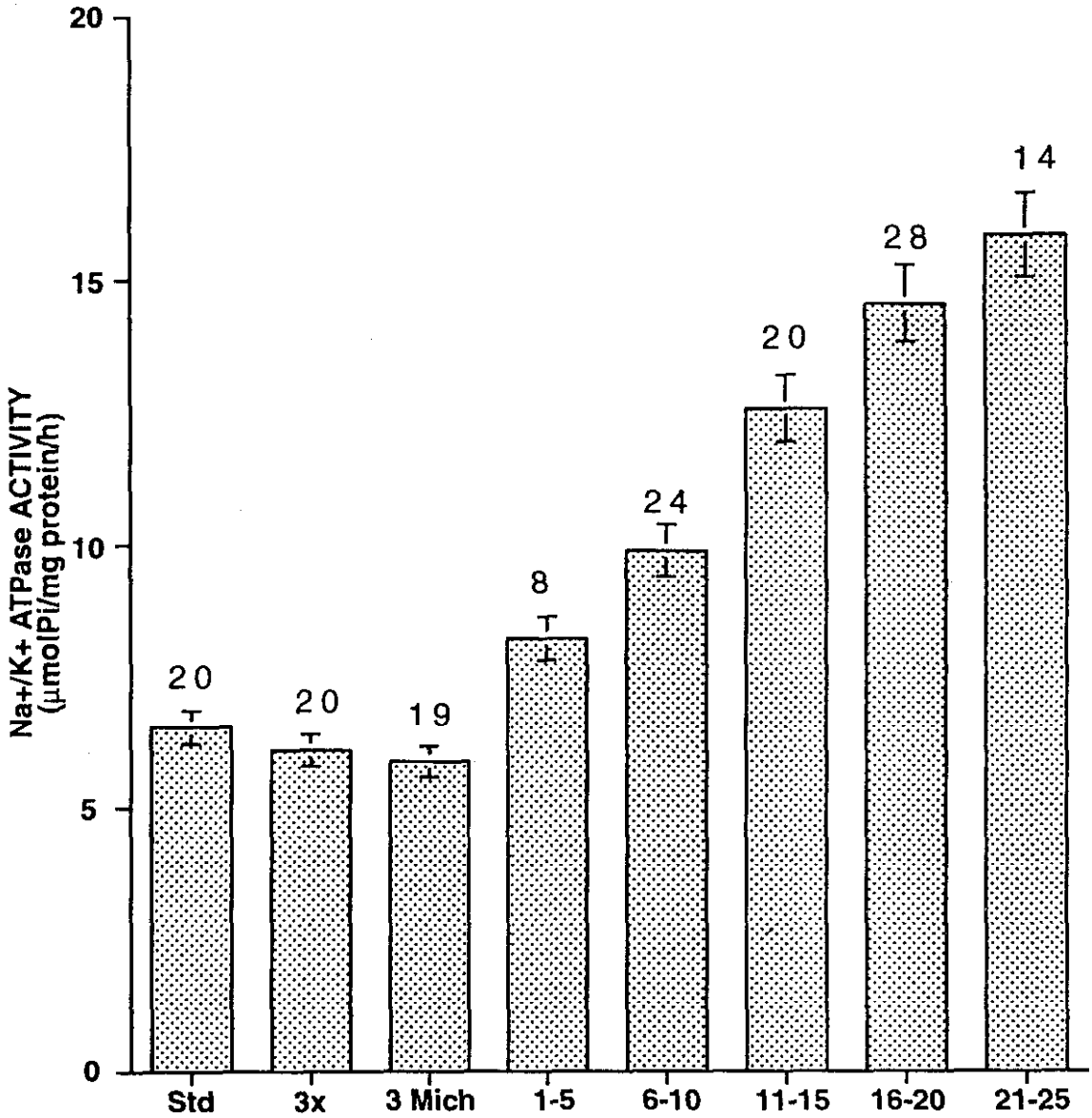


Figure 44. Comparison of Na+K+ ATPase in the gills of juvenile spring chinook salmon (Willamette Hatchery, 1992 brood-year) from several locations and times after release in 1993. From left, first three bars represent hatchery values for indicate treatment; other bars represent values for indicated treatment; other bars represent values from Sullivan trap collections. Number of fish below standard error bars (see text).

1990

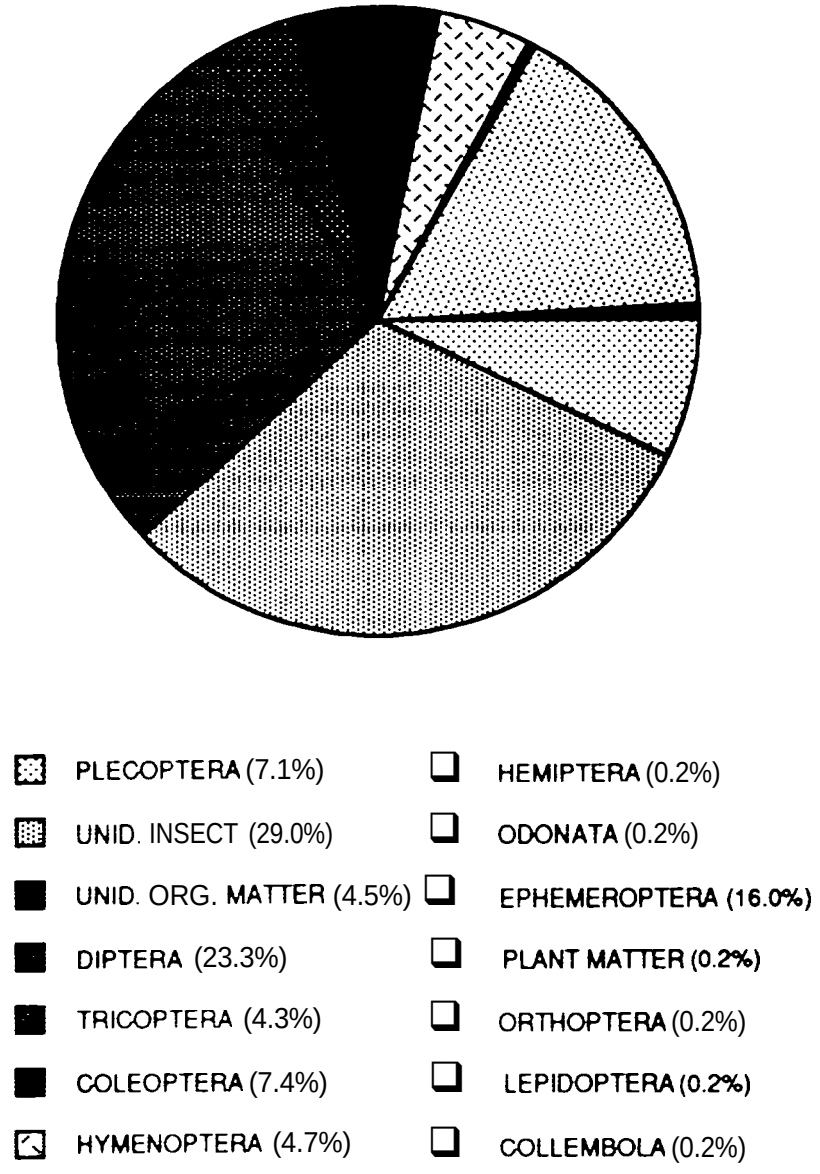
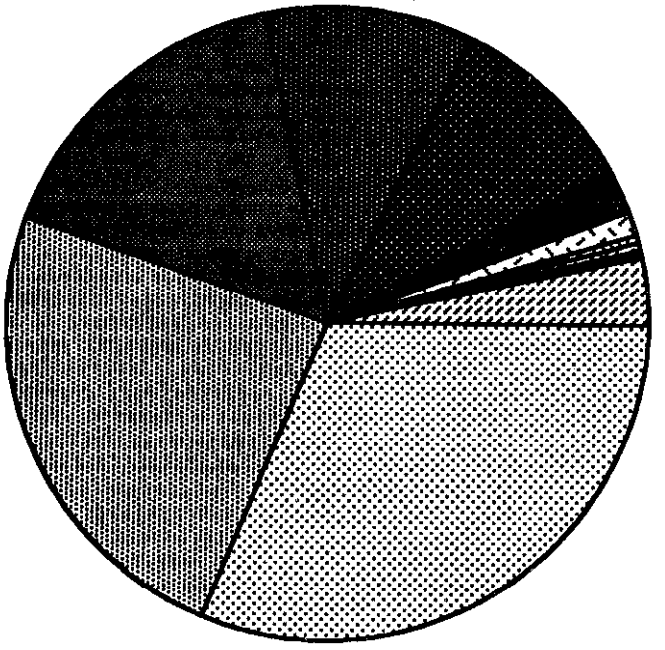


Figure 45. Qualitative analysis of gut contents of juvenile spring chinook salmon collected in the Willamette River in 1990. Food items are listed as percentages of total volume. Total n = 105.

1991



PLECOPTERA (31.2%)
UNID. INSECT (24.2%)
UNID. ORG. MATTER (16.2%)
DIPTERA (10.5%)
TRICOPTERA (9.7%)
COLEOPTERA (2.2%)
HYMENOPTERA (1.2%)
HEMIPTERA (0.4%)
ODONATA (0.4%)
EPHEMEROPTERA (0.2%)
PLANT MATTER (0.2%)
AMPHIPODA (3.5%)

Figure 46. Qualitative analysis of gut contents of juvenile spring chinook salmon collected in the Willamette River in 1991. Food items are listed as percentages of total volume. Total n = 213.

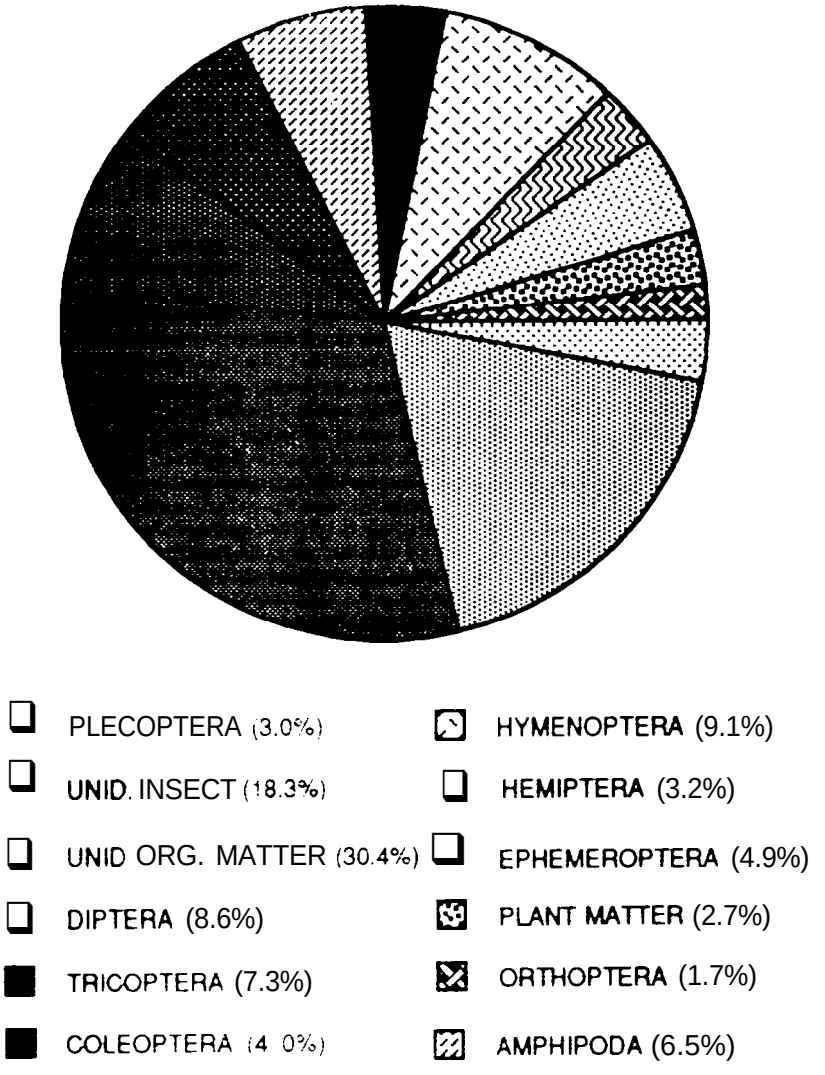


Figure 47. Qualitative analysis of gut contents of juvenile spring chinook salmon collected in the Willamette River in 1992. Most samples collected at Willamette Falls in the PGE Sullivan trap. Food items are listed as percentages of total volume. Acarina and Odonata comprised less than 1% of the sample and are not shown. Total n = 84.

1993

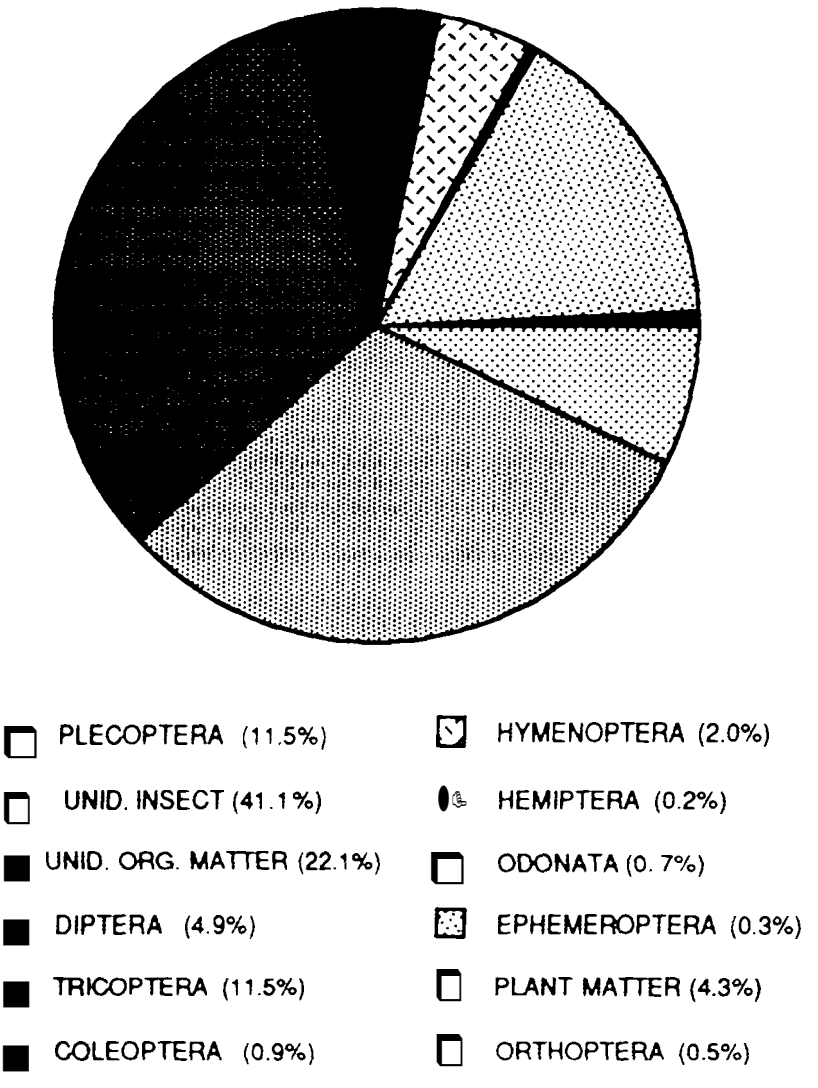


Figure 48. Qualitative analysis of gut contents of juvenile spring chinook salmon collected in the Willamette River in 1993. Most samples collected at Willamette Falls in the PGE Sullivan trap. Amphipoda comprised less than 0.1% of the sample and is not shown. Total n = 251.

DISCUSSION

Effect of Rearing Treatment on Migratory Ability and Behavior

We compared the time in hours for radio-tagged outmigrant smolts to reach specific Willamette River locations on their outmigration in 1991 and 1993 to evaluate the effects of rearing treatment on migratory ability and behavior; while fish released in 1992 were the first treated cohorts, the problems we encountered with transmitter failure and fish sizes obscure these data. For both 1991 and 1993 we have evaluated migration time to locations 37 and 107 km downriver. For 1993 we also evaluated performance to 243 and 280 km Willamette Falls). Analysis of variance at the 95% confidence level showed no significant differences.

In Table 10, we compare the number of radio-tagged smolts which we contacted at Willamette Falls, or to within 7 km of Willamette Falls. Depending on the year or treatment this varied between none and 100%. We have most confidence in the 1991 and 1993 data. In 1991 smolts from the triple density treatment were the most successful migrants (58%), with smolts from third Michigan treatments second (27%), followed by those from the standard treatment (13%). In 1993, fish from these three treatments arrived in nearly uniform numbers (56 to 61%), while all 10 (100%) of the smolts from the standard treatment released from a net pen at Pengra Ramp reached Willamette Falls. Again we can demonstrate no consistent difference between migratory ability of smolts reared in different treatments.

Previously we described collection of smolts at the Willamette Falls Sullivan Plant evaluator, and how the proportion of fish from the three treatments differed significantly from a null hypothesis in 1992, but supported the null hypothesis in 1993. Figures 49 and 50 show the percent of smolts from all treatments pooled for four day intervals. For 1992, covering nearly a month of sampling, the relationship between fish collected from different treatments was uniform: most smolts were from triple density treatments, with standard treatments next, followed by third Michigan. This and the above relationship strongly suggests that smolts from third Michigan treatments did not arrive at Willamette Falls when their siblings did; perhaps they experienced greater mortality (but see below). The data for 1993 shows no pattern, and therefore supports our observation of a more uniform arrival. We cannot unconditionally equate capture time with arrival time because the pre-trap holding tank at Sullivan provides refuge for some fish for up to two weeks after they arrive (D. Clark, PGE, pers. comm.). Keefe, et al. (1993) report on migration time of cold branded smolts over 108 km in the Columbia River from Umatilla Hatchery (Irrigon) to John Day Dam. Fish reared in Michigan treatments required more time to reach John Day than those reared in Oregon treatments, but the authors report that ". brand identification concerns make these results equivocal" (p. 40). The Umatilla results showed remarkable consistency over

Table 10. Arrival of radio-tagged juvenile spring chinook salmon at Willamette Falls or within 7 km of the Falls

YEAR	STANDARD		TRIPLE DENSITY		THIRD MICHIGAN		STANDARD (NET PEN)		OVERALL	
	number	%	number	%	number	%	number	%	number	%
1989	1/15	7								7
1990	11/31	36								36
1991	2/15	13	7/12	58	4/15	27			13/42	31
1992-1	3/5	60	0/5		1/8	13			4/18	22
1992-2	0/17		0/4		0/8				0/29	
1993	11/19	58	11/18	61	10/18	56	1 10/10	100	42/65	65

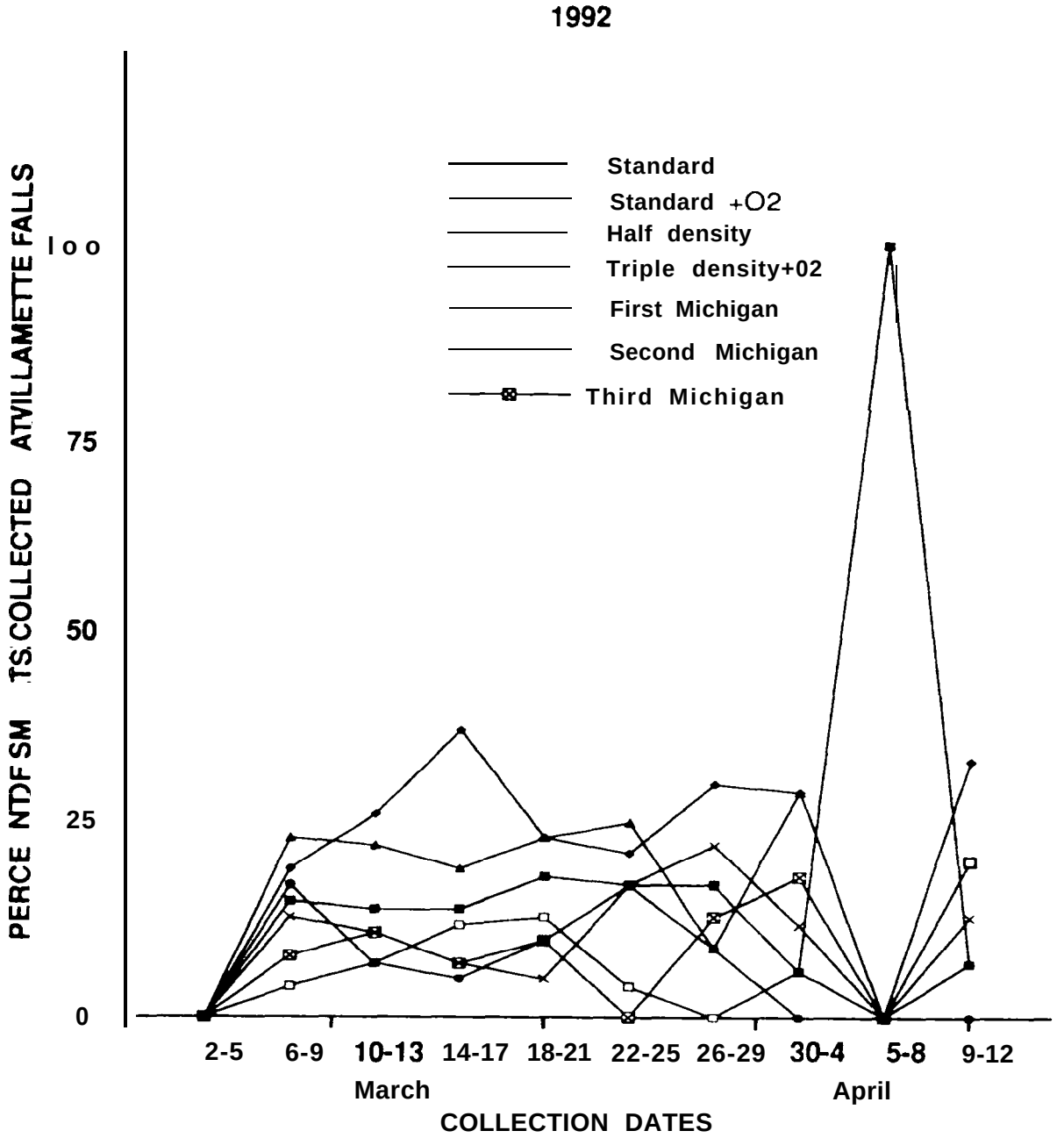


Figure 49. Collection of outmigrant juvenile spring chinook salmon representing different **treatment** groups released from Willamette Hatchery in 1992. Data are expressed as the percent of fish collected during each four day interval representing indicated treatment groups. Adipose clipped juveniles were collected at the PGE Sullivan Evaluator. Coded wire tags were analyzed by ODFW to determine treatment origin.

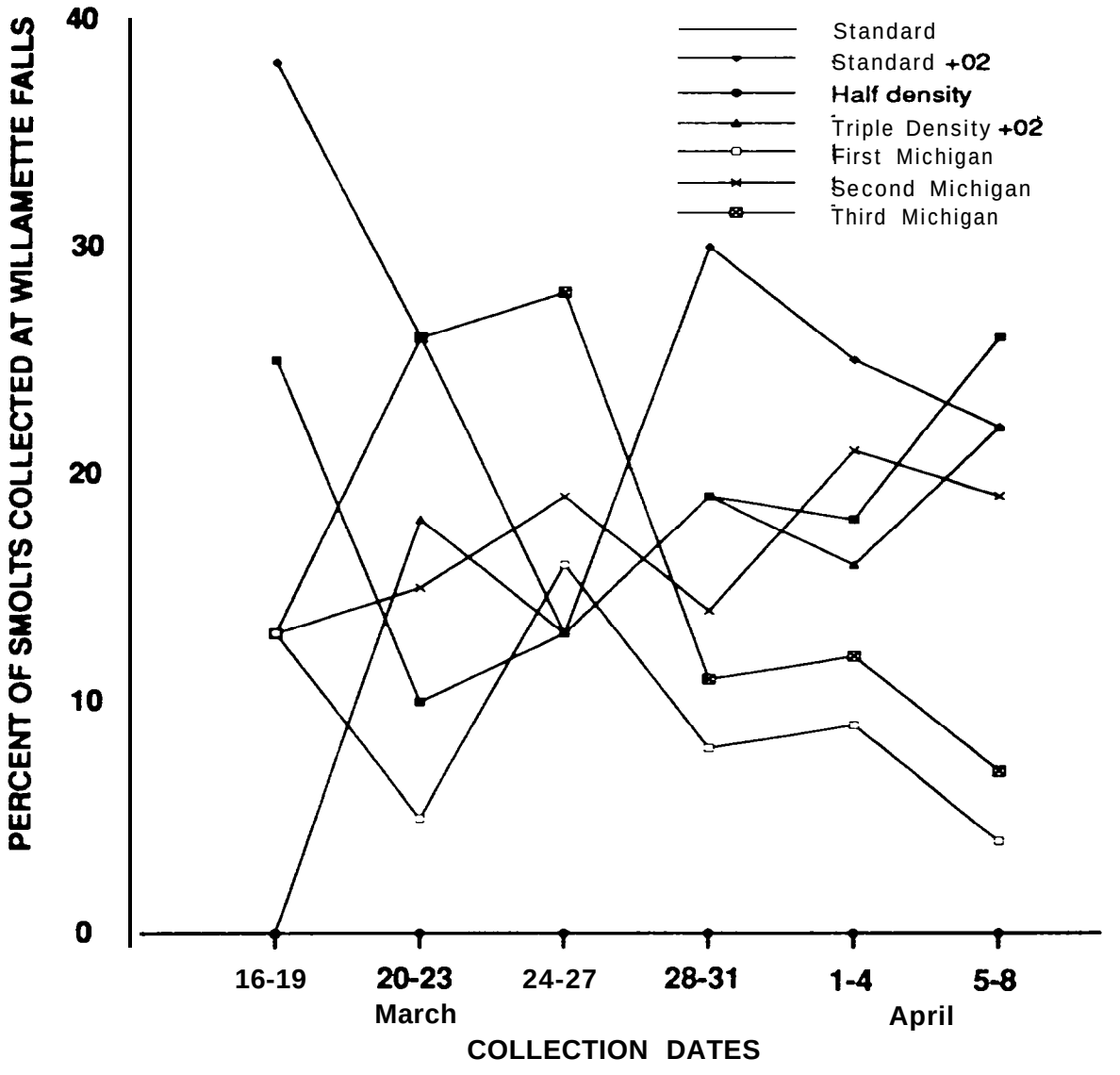


Figure 50. Collection of outmigrant juvenile spring chinook salmon representing different treatment groups released from Willamette Hatchery in 1993. Data are expressed as the percent of fish collected during each four day interval representing indicated treatment groups. Adipose clipped juveniles were collected at the PGE Sullivan Evaluator. Coded wire tags were analyzed by ODFW to determine treatment origin.

several years with variation in flow. During the period of smolt outmigration in 1992 the Willamette River flow had overall low flows which we suspect contributed to poor outmigration for fish reared in third Michigan treatments and which may have been in poor shape anyway. In addition some recent data suggests that a period of rapid growth stimulates smolting in chinook (Dickhoff et al., 1994). The very cold water at Willamette Hatchery may not accommodate such a growth period in February just prior to smolt release.

Survival of Hatchery Outmigrants

A conservative estimate of survival for outmigrating smolts is obtained from counting radio-tagged smolts released upstream which reach Willamette Falls, 280 km downstream. The estimate is conservative and a minimum figure because, 1) even with the best radio reception some transmitters may not be heard, 2) some transmitters could fail during the outmigration, and 3) some transmitters could be regurgitated. From Table 10 the overall survival is as low as none for the second release in 1992, to 65% for the 1993 release. Data collected in 1992 must be considered with caution because of the know-n transmitter failure for the first release; for the second release flow-s and therefore fish movements were very slow. We have reliable data for 1991 and 1993, but have the most confidence in the 1993 data because we were able to use remote data logging receivers most effectively.

For 1991 and extending the lowest location to RKM 63 (260 KM downriver), the overall survival estimate is 33%, with a low of 13% for fish in standard treatments and 54% for those in triple density treatments (Table 11). For 1993 and extending the lowest location to RKM 50, (273 KM downriver), the overall survival estimate is 66%, with a low of 58% for fish from standard treatments and 100% for fish from standard treatments released from the net pen (Table 12); overall these data are very consistent and form the basis for a credible minimum survival estimate.

Additional evidence that smolts reared in third Michigan treatments do not survive as well as those from others comes from preliminary coded wire tag returns of adults to Dexter Pond on the middle fork of the Willamette River in 1994 (J. Sheehan, ODFW, pers. comm.). In addition survival indices of cold branded chinook smolts released in 1993 from the Umatilla Hatchery suggested that both yearlings and subyearlings reared in recycled water survived poorly compared with those in first pass water in either Oregon or Michigan Ponds (Keefe, et al. 1993).

Additional evidence for minimum survival estimates of chinook smolts over long distance comes from our work in the Lower Columbia (Schreck et al., 1994). In 1994 radio-tagged smolts from Lower Granite Dam, used in evaluation

Table 11. Migration success of radio-tagged juvenile spring chinook salmon over 243 KM in the Willamette River (1991)

	STANDARD	TRIPLE DENSITY	3RD MICHIGAN	TOTAL
TOTAL RELEASED AT PENGRA	15	13	15	43
NUMBER CONTACTED AT WILSONVILLE (RKM 63)	0	1	3	4
NUMBER CONTACTED AT WILLAMETTE FALLS (RKM 43) OR BELOW	2	6	4	12
TOTAL REACHING RKM 43 OR BELOW	2	7	5	14
PERCENT REACHING RKM 43 OR BELOW	13%	54%	33%	33%

Table 12. Migration success of radio-tagged juveni e spring chinook salmon over 273 KM in the Willamette River (1993)

	STANDARD	TRIPLE DENSITY	3RD MICHIGAN	NET PEN	TOTAL
TOTAL RELEASED AT PENGRA	19	17	17	0	63
NUMBER CONTACTED AT RKM 50	10	8	9	9	36
NUMBER CONTACTED AT WILLAMETTE FALLS (RKM 43)	7	4	7	5	23
NUMBER CONTACTED AT RKM 43, NOT AT RKM 50	1	3	1		6
TOTAL REACHING RKM 43	11	11	10	10	42
PERCENT AT RKM 43	58%	65%	59%	100%	66%

of the Columbia River barge transportation program, reached a point 160 km downstream of release below Bonneville Dam at rates approaching 70%.

Temporal Pattern of Migration

Radio-tagged fish provide the most precise estimate of outmigration time from hatchery release to Willamette Falls; these are corroborated by trap counts at the PGE Sullivan Plant evaluator and seine hauls at Peach Cove (RKM 52) (Table 13). The range of earliest radio-tagged smolt arrival at Willamette Falls is 2.0 days after release (1991) to 8.5 days (1992). The range of last smolts to arrive is 3.25 days (1991) and 11.5 days (1991). The poisson distribution of arrival time, skewed to the right (see below), and the possibility that really late arriving fish could be missed, should be considered when interpreting the latter. The early, and probably majority of arrivals are of interest because of general uniformity over a number of years and flow conditions; there are also clear differences correlated with flow. Radio-tagged smolts arrived at Willamette Falls in about the same time after release in 1989, 1990, 1991 and 1993. Willamette River flow (measured at Salem) during the outmigration in these years was either above 20 kcfs and falling slowly, or above 13 kcfs and rising rapidly (Table 13). In 1992 the river flow was 15 kcfs and falling, and smolts reached the falls in about twice the time of other releases.

We last captured smolts at the Sullivan evaluator released from Willamette Hatchery treatment groups at 37 days after release in 1992 and 31 days after release in 1993. We cannot be certain that large numbers of smolts continued to arrive at these times, because the pre-trap raceway at Sullivan provides refuge for some fish up to two weeks after they arrive (D. Clark, PGE, pers. comm.).

Fish velocities were not uniform over the 280 KM migration from Pengra Access to Willamette Falls (Figures 8, 10, 14, 18, 22, and 27). For 1989 through the first release in 1992, the most rapid migration rates were found between Eugene (RKM 286) and Marshall Island (RKM 274), a river reach with a steep gradient. During the second release in 1992, when flows were the lowest of any during our studies (13 kcfs and below), fish velocities were variable, with apparently the most rapid migration between Independence (RKM 155) and Newberg (RKM *80).* In 1993, again with our most complete data set, the most rapid fish velocities were recorded between Corvallis (RKM 216) and Newberg; fish traveled a little slower in the upper reaches, and very much slower in the lower reaches. So, in general, smolts traveled most rapidly in the middle reaches of the Willamette River.

Our work on the Columbia River (Schreck, et al. 1994; Snelling and Schreck, 1993) shows a strong correlation between river flow and smolt migration speed with radio-tagged smolts moving at about river velocity. Currently

Table 13. Summary of outmigration travel time of juvenile spring chinook **salmon** in **the** Willamette River, 1989 through 1993

YEAR	DAYS TO REACH WILLAMETTE FALLS OR VICINITY				FLOW (KCFS) AT SALEM
	RADIO-TAGGED	SEINED AT PEACHCOVE	TRAPPED AT SULLIVAN FIRST	TRAPPED AT SULLIVAN LAST	
1989	3.25-4.25 (2)				23, FALLING
1990	3.3-6.8 (10)	**7**			**29,** FALLING
1991	**STANDARD** 3.6-5.25 (2) **TRIPLE DENSITY** **2.0 - 3.25** (6) **THIRD MICHIGAN** **3.25 - 4.3** (4)	15			13, RISING TO 60 OVER 4 D
1992-1	STANDARD **6.3 -** 11.5 (3) **TRIPLE DENSITY** NONE **THIRD MICHIGAN** **8.5** (1)		**3**	**> 37**	15, FALLING
1992-2	NONE				9, FALLING
1993	**STANDARD** **2.5 - 4.8 (6)** **TRIPLE DENSITY** **2.75 - 7.0** (4) **THIRD MICHIGAN** **2.6 - 4.9** (6) **NET PEN** **2.8 - 5.3** (5)		**2**	> 31	15, RISING TO 80 OVER 4 D

reported information on fish marked with PIT tags and cold brands in the Columbia is equivocal with respect to migration speed because smolts are known to hold in front of dams before being detected in fish handling facilities (Rondorf, NBS, pers. comm.; most recent informa tion at L ower Granite Dam).

Variation in Outmigration Patterns

Since 1992, whin PGE began trapping large numbers of spring chinook smolts in the Sullivan evaluator, a poisson distribution of fish arrival (skewed to the left) has emerged (D. Clark, PGE, pers. comm.). In 1992 the first hatchery fish arrived in the last half of February (less than 1% of the run), with a peak of 36% arriving in the latter half of March about 15% of the run arrived in April (Figure 51). For 1993 the first hatcher), fish arrived the first half of March (about 2% of the run), with a peak of 32% arriving in the latter half of March; about 26% of the run arrived in April, and about 1% in May (Figure 52). ODFW releases some spring chinook in the fall, thus a significant portion of the yearly total arrived in late November and early December. Our data from radio-tagged fish approximately reflect these patterns although the sample is small, and battery life is short. .

Some of the variables responsible for among year variation include: release date, river flow rate, and temperature. And related to these are the behavior of smolts delaying to feed, and fish diverted to back eddies or flooded fields in very high flows. Sullivan trap counts in 1992 (a low flow year) compared with 1993 (a high flow year)_ illustrate the effect of flow on migration timing (above).

The effect of release date was seen in 1993. Were the fish released in early March as ODFW planned, they would have encountered flows of 13 kcfs, rising to 30 kcfs and then falling back to 15 kcfs over the two weeks following release; the migration would probably have been similar to 1992. But instead a delayed release coincided with a major frshet, with resulting rapid outmigration. In any case 2% of the year's total arrived in the first half of March in 1993, compared with 25% of the total during the same period in 1992 (above).

We believe that the majority of outmigrating smolts feed, based on direct observation of gut contents and surfacing behaviour (see below). For each of the five years of this study we found food in the stomachs of most of the smolts we examined. We also observed fish surface feeding at several locations along the outmigration route in all years but 1991 and 1993. The length of time fish spend feeding will influence outmigration timing; during low flow conditions fish are more likely to feed. A case in point occurred after our second release in 1992, when river flows were the lowest during these studies. From 0850 to 1245 h on 25 March we tracked a smolt traveling at 3 km/h. At noon the sky cleared, an insect emergence was in progress, and the fish stopped below a riffle (RKM 274)

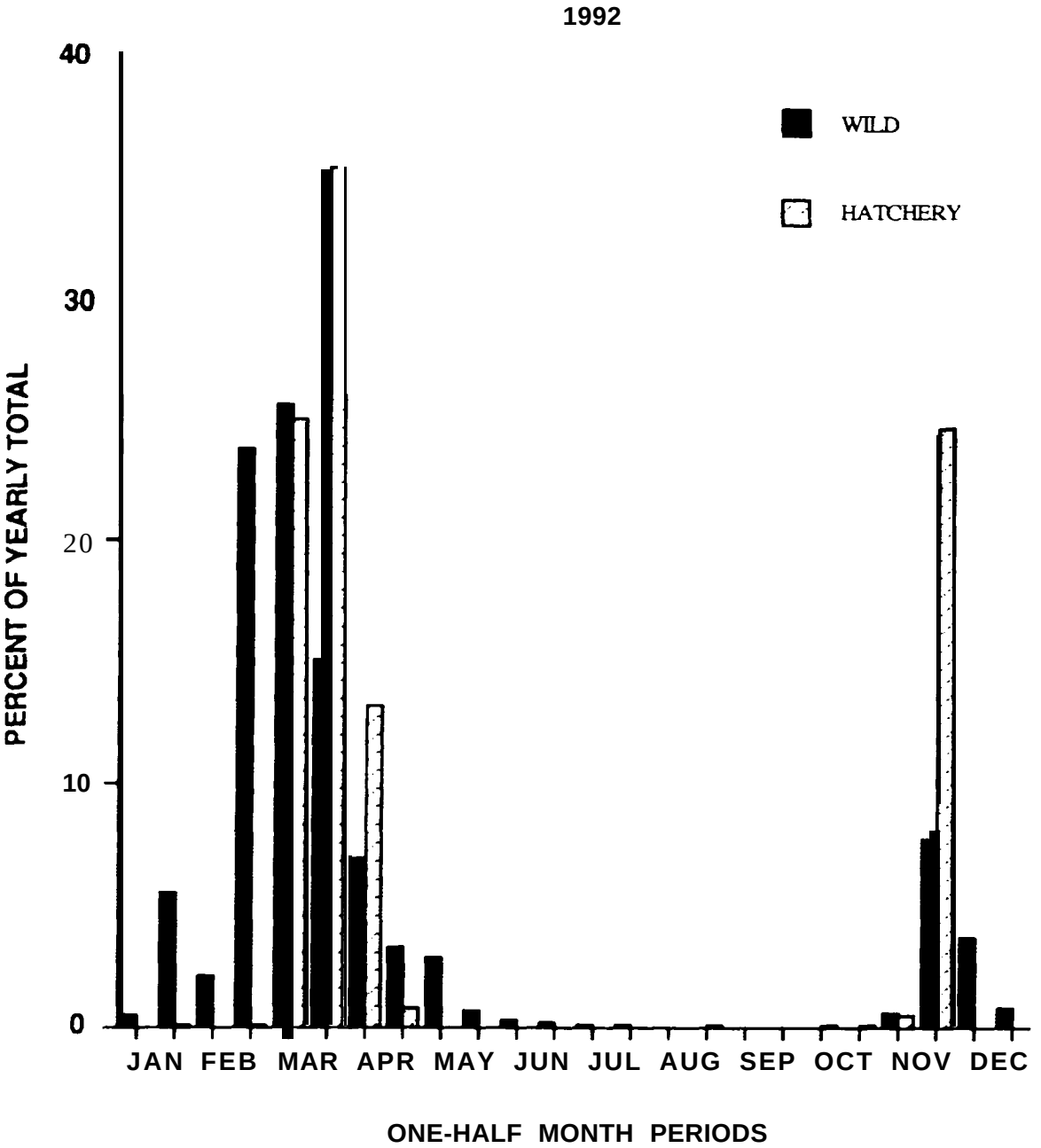


Figure 5 1. The relative abundance and timing of spring chinook juveniles arriving at Willamette Falls in 1992. Fish were collected at the PGE Sullivan Plant Evaluator. Adjustments were made by expanding the counts based on hourly sampling effort and for capture efficiency at Sullivan related to flow based on the Willamette Falls model which assumes fish are evenly distributed in the water column and that Sullivan takes 5 kcfs of flow, Data courtesy of Don Clark, PGE.

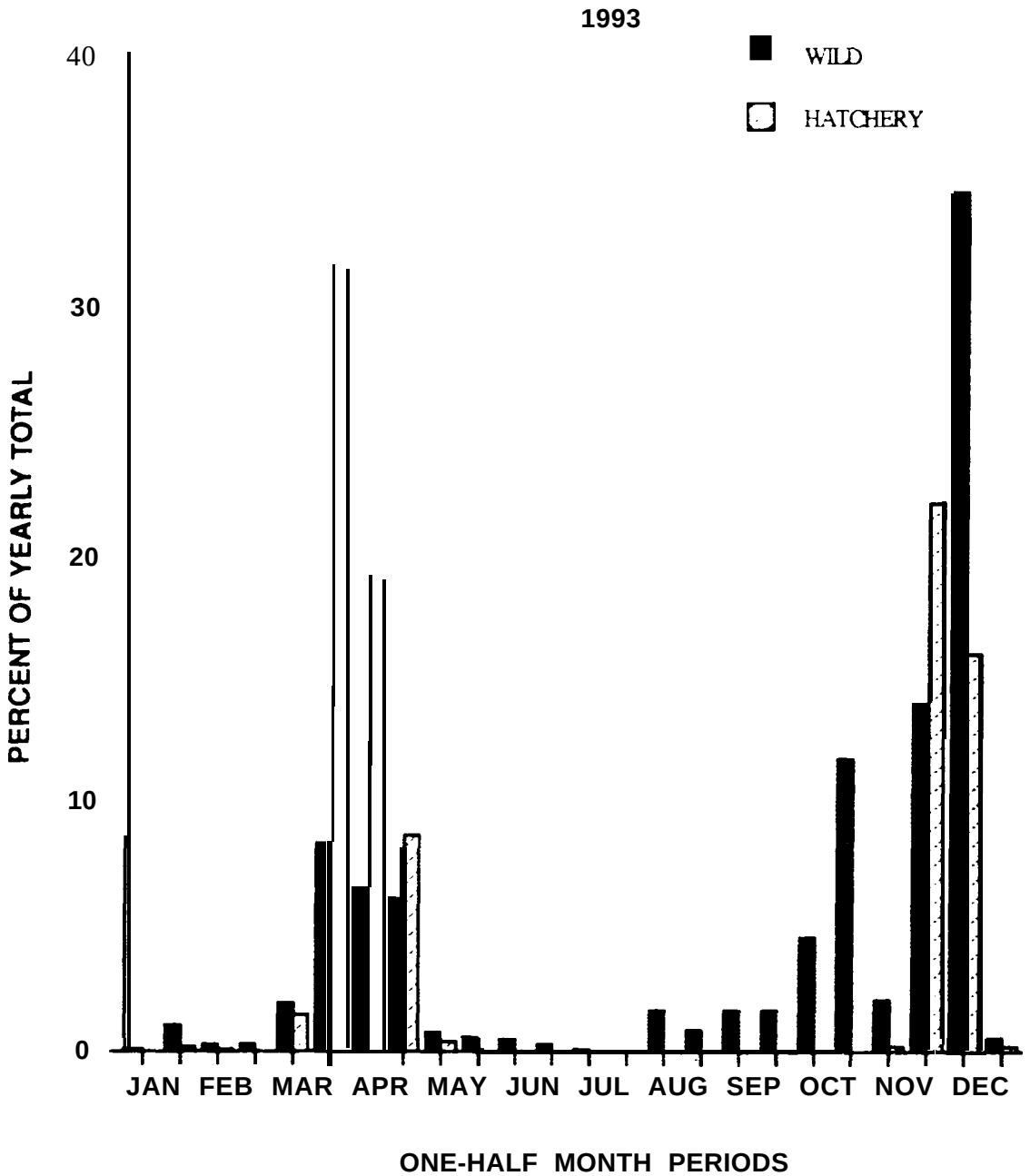


Figure 52. The relative abundance and timing of spring chinook juveniles arriving at Willamette Falls in 1993. Fish were collected at the PGE Sullivan Plant Evaluator. Adjustments were made by expanding the counts based on hourly sampling effort and for capture efficiency at Sullivan related to flow based on the Willamette Falls model which assumes fish are evenly distributed in the water column and that Sullivan takes 5 kcfs of flow. Data courtesy of Don Clark, PGE.

where several smolts were surfacing. It remained there until 1919 h (dark) when it resumed downstream migration. The following day we follow-ed a second radio-tagged fish which stopped in the same location (above) at 1330 h, and resumed migration at 1803 h, 30 min. after clouds covered the skv. This same fish later traveled as far as RKM 71, showing it to be an active migrant.

Smolts may also delay during high water years when they are diverted out of the main river channel. In 1993 we found five radio-tagged fish in the middle third of the Willamette River, having strayed into flooded fields or woodlands adjacent to the river. One of these subsequently re-entered the main river and traveled 119 km further downstream. We do not know what happened to the others. Entrapment of smolts into water irrigation diversions in the Columbia River contributes to significant loss of downstream migrants in eastern Oregon and is of major interest to ODFW (B. Kepshire, ODFW, pers. comm.)

Migration Closely Correlated With River Flow

A growing body of evidence points to a strong positive correlation between the velocity of outmigrating smolts and the velocity (the metric is usually flow) of the river in which they are swimming; the relationship is linear over short river velocity ranges and curvilinear (polynomial relationship) over wider ranges (Schreck, et al. 1994; Snelling and Schreck, 1993). The relationship between flow in cfs at Salem (RKM 135) and mean river velocity at all locations measured has an r^2 of 0.34. Our data on river velocitv from 1991 to 1993 are quite variable. In 1991 fish traveled 1.6 times faster than or at river velocity as far downstream as Corvallis, and thereafter as slow as half river velocity; during the outmigration the river flow in kcfs increased rapidly. In 1992, when flows were low and decreasing, smolts outmigrated at 0.5 to 0.8 of the river velocity. And in 1993, when flows were rapidly increasing, smolts traveled up to 1.5 times river velocity. Velocity is related to the cross sectional area of the river bed, therefore small changes in river height have little effect on velocity. Comparing river velocity at all specific river locations with the velocity of fish past each location gives a weak correlation (r^2 = 0.27). The regression of mean flow at Salem compared with overall fish velocity from release to the Falls (280 km) is more strongly correlated (r^2 = 0.66). And finally the flow at Salem regressed with fish velocities near that point gives an intermediate correlation (r^2 = 0.45) (Figs. 53-56).

Examination of the migration figures (see Results) shows clearly that individual fish travel at different and variable speeds. Our observations indicate that stopping to feed, or being carried into backwaters could account for these differences.

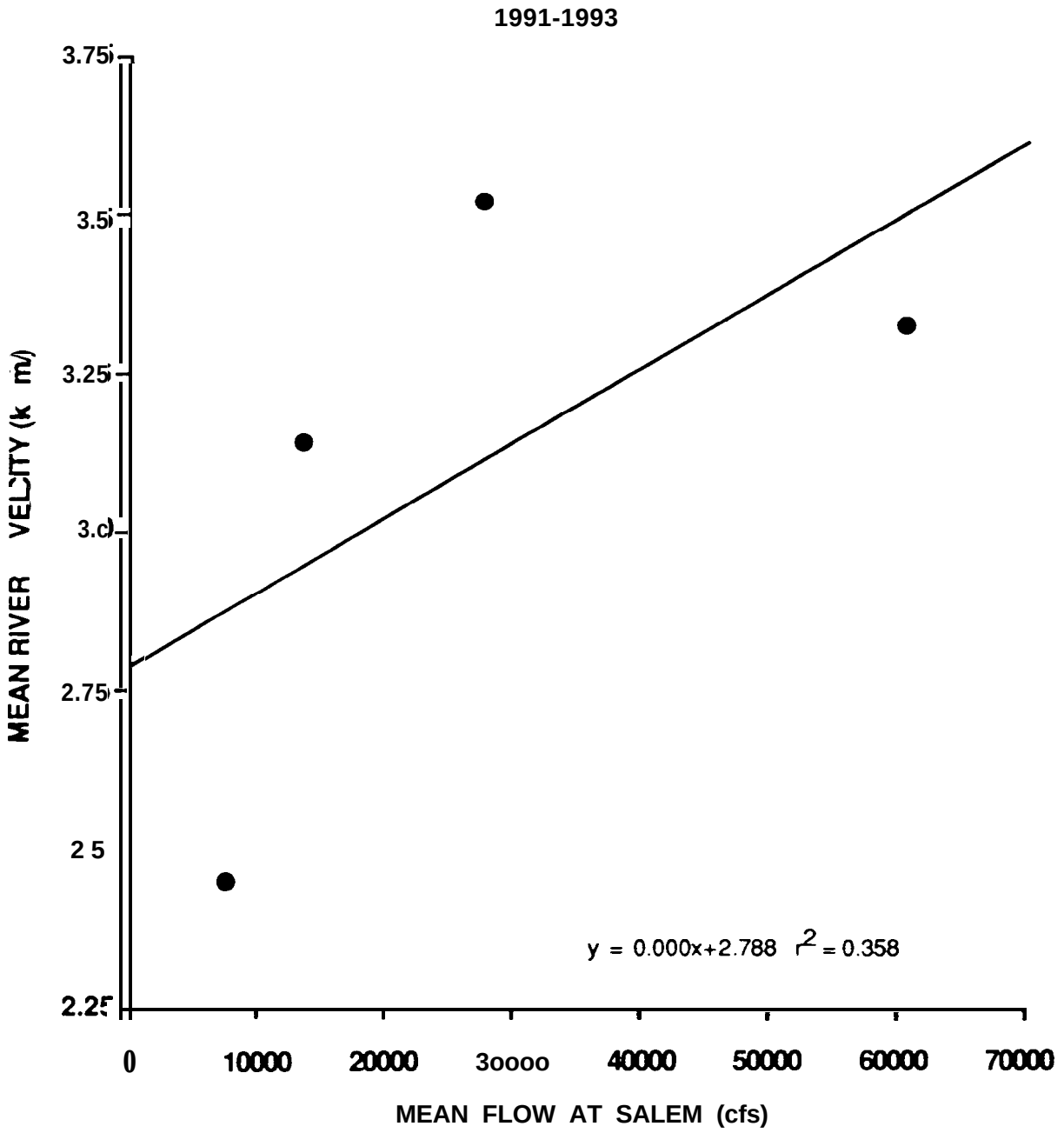


Figure 53. Regression of mean flow at Salem and mean river velocity at all locations during the times radio-tagged **juvenile spring chinook salmon were outmigrating in the Willamette** River, 1991-93.

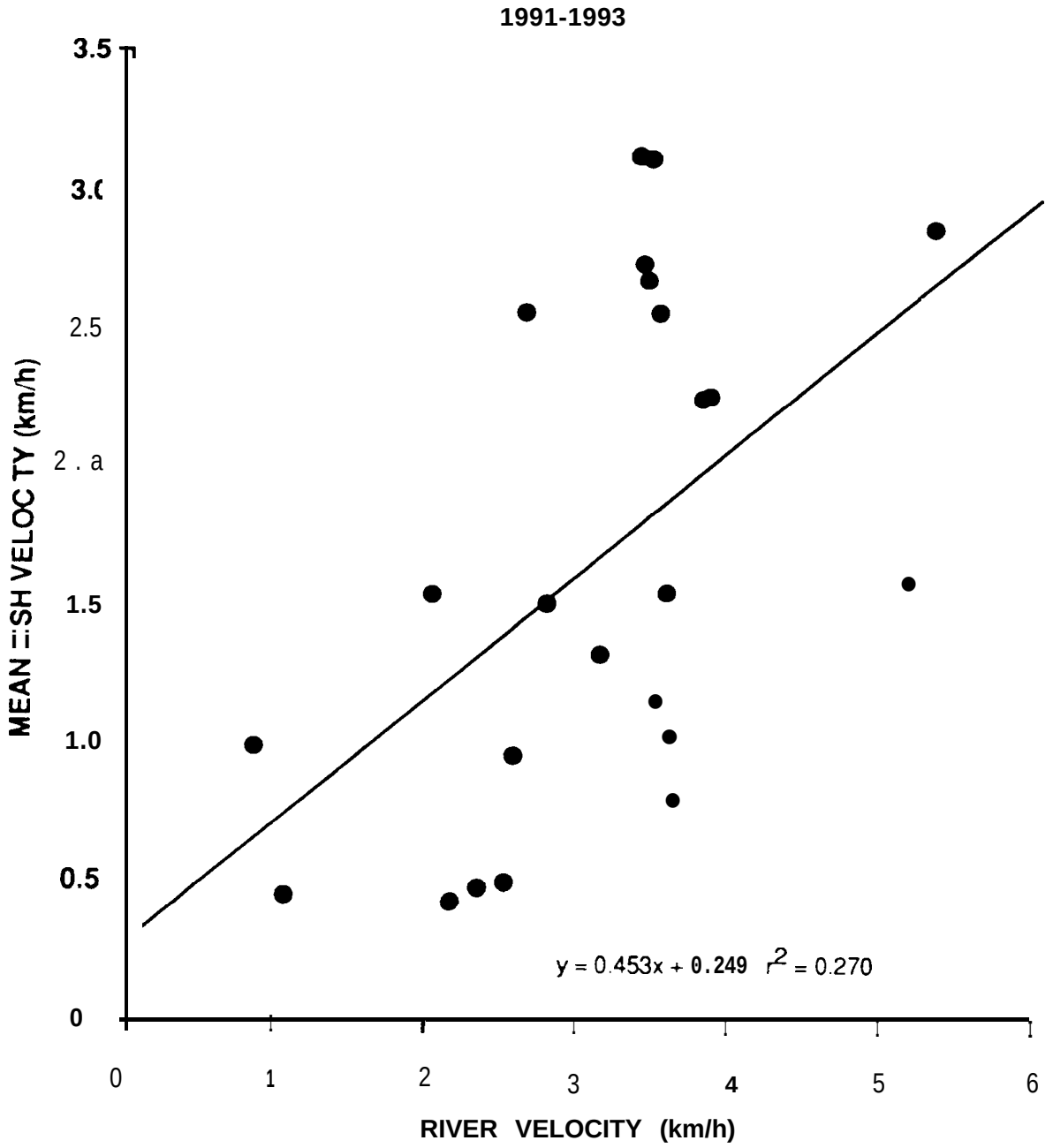


Figure 54. Regression of outmigration velocity of radio-tagged juvenile spring chinook salmon and river velocity measurements at all locations along the Willamette River and all years, 1991-1993.

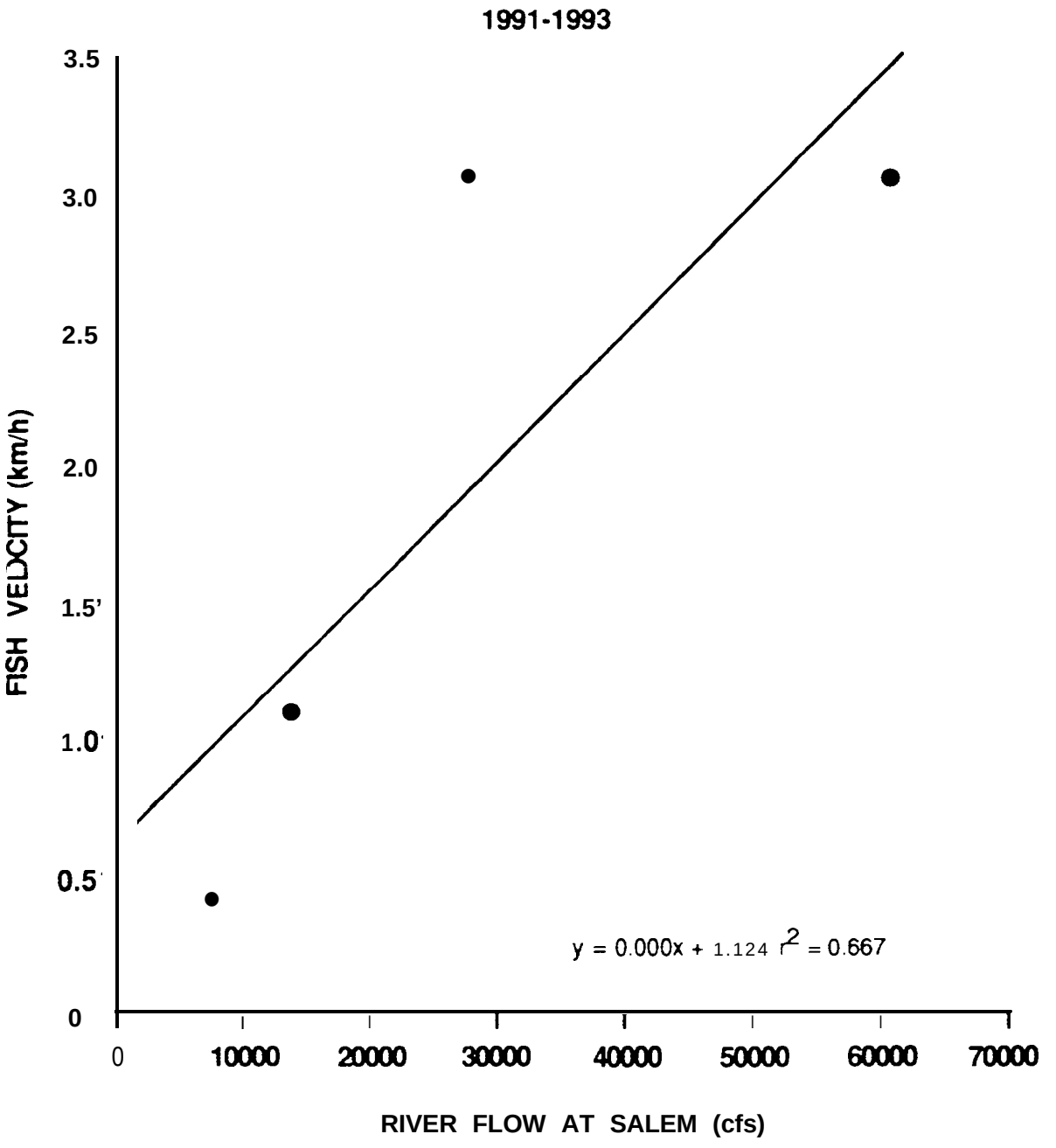


Figure 55. Regression of mean outmigration velocity of juvenile spring chinook salmon over the entire migration route (from release at Pengra access to Willamette Falls) and mean flow at Salem, 1991-93.

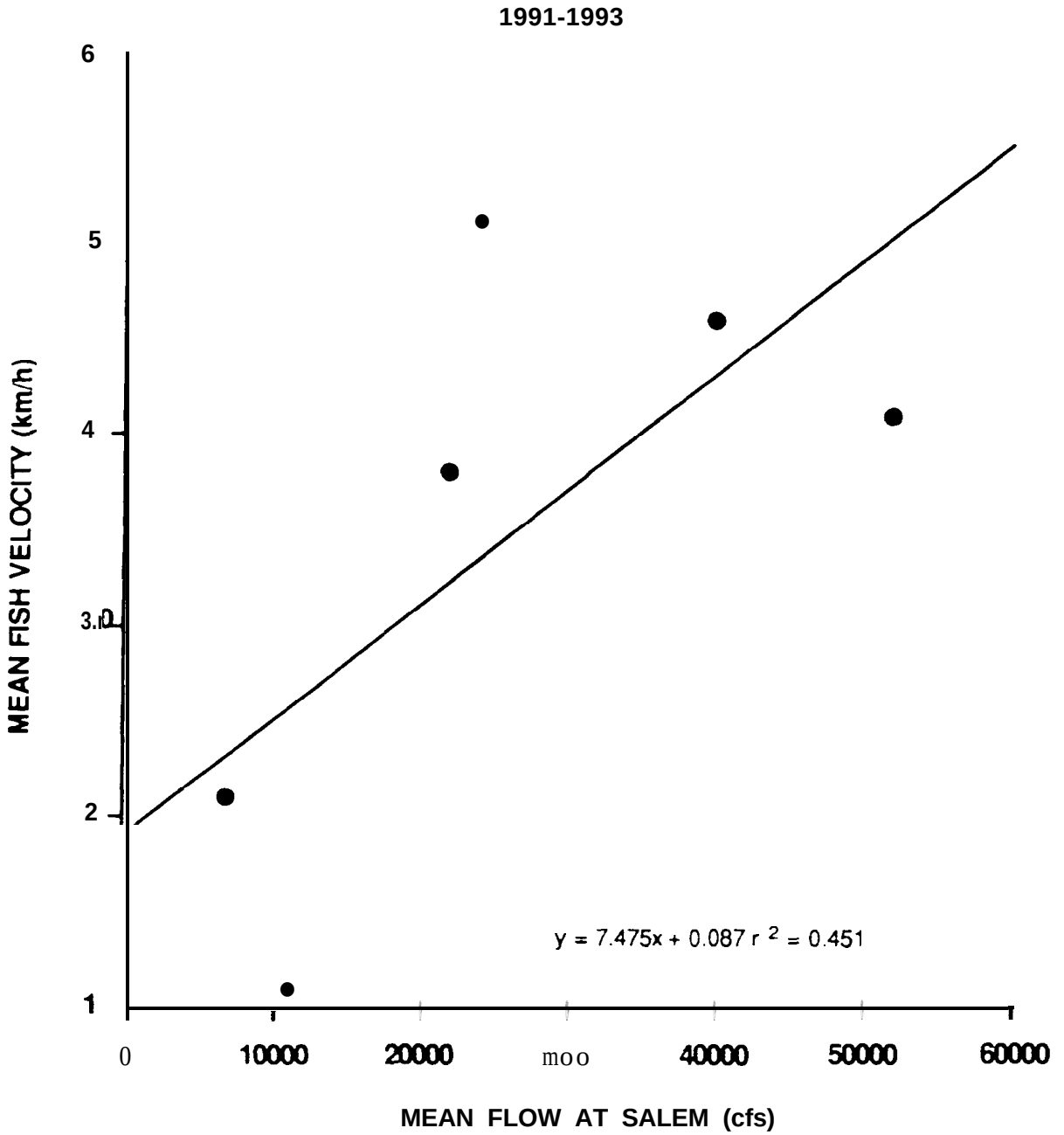


Figure 56. Regression of outmigration velocity of radio-tagged juvenile spring chinook salmon between Independence and San Salvadore (locations bracketing Salem) and Willamette River flow at Salem, 1991-1993.

Feeding During the Migration

Based on analysis of stomach contents and from direct observations on the river we feel that many smolts feed during the outmigration. When fish were moving more slowly, such as in the low flow-s of 1992, we were able to observe more feeding behavior than during high flows. During our studies hatchery fish began their journey non-volitionally and migrated quickly with the flow, unless flow was low (see above) That the); feed may be related to their former hatchery condition, in which food was offered several times daily. Prior to channelization of the Wiliamette River (Sedell and Frogatt, 1984) there must have been numerous back water areas where fish could rest and feed. Many of these are unavailable today. In the absence of productive feeding and resting areas the most successful strategy (both management and evolutionary) may be for outmigrant chinook to move fish quickly downstream toward more rich ocean or estuary conditions.

Few Juveniles Residualized

Because our radios transmitted fourteen days or less we were unable study the behavior of individual smolts over weeks or months to determine whether they truly residualized. The movement figures (Results) show that some fish delay a few days before either dying, or regurgitating their tags; we do not think many- of these lived.

Our attempts to electroshock smolts at various locations along the river allows a better evaluation of residualism. In 1990 we found smolts at all locations we sampled along the Willamette River up to a month after the hatchery releases. Those fish captured in the upper river three weeks after release were definitely from our release groups, and may reveal more than lower river samples, some of which were released from other hatcheries. In 1991 just 13 days after releases from Willamette Hatchery we found only two smolts at Pengra Access, and these were not adipose-clipped. In 1992 we captured five adipose-clipped smolts at Pengra Access 15 days after release, and one smolt 64 days after release. And in 1993 we captured no smolts a Pengra Access 36 days after hatchery release.

That hatchery smolts continue to arrive at Willamette Falls (Sullivan counts) several months after release suggests that the hatchery population includes some stragglers. We have documented Willamette Hatchery smolts arriving more than a month after release.

The most clear evidence of true residualism from our work is two smolts we captured at Sullivan in March 1992, which had been released at Dexter Ponds in August 1991. We were unable to find references to residualism in the literature.

Transport and Release Are Stressful

Plasma cortisol was 5 to 12 times higher in smolts after crowding, transportation and release, than in smolts netted from raceways. We found that smolts from different treatments and different years mounted different stress responses (see also Schreck et al., 1994). In 1991 smolts from triple density and third Michigan treatments had significantly lower plasma cortisol at release than did those from standard treatments; resting plasma cortisol was also significantly lower in fish from third Michigan treatments. In 1992 we detected no differences between treatments, however. In 1993 the differences were reversed from 1991, with resting cortisol in fish from standard treatments significantly lower than the other groups. At release fish from the triple density group had higher plasma cortisol than fish from either the standard or third Michigan groups. This suggests that transportation clearly stresses chinook smolts and the response is unrelated to how they were reared. But probably there are factors such as genetics, weather, and other variables from year to year which obscure any consistent pattern if one exists. Keefe, et al. (1994) report that Michigan reared fall chinook had significantly greater basal cortisol levels than Oregon reared controls, suggesting that the Michigan reared fish may experience chronic stress while in the hatchery.

We **have also** observed the behavior of chinook smolts released from hatchery trucks. Some of the fish are disoriented, either swimming rapidly into shallow water or up on the shore, or planing along the water's surface. Apparently some of these are affected beyond recovery, as dead or dying smolts remain after release. Hatchery personnel and truck drivers have reported to us that the incidence and severity of disorientation varies with the specific truck used in hauling.

While the sample is very small (10 fish), the performance of smolts from the standard treatment placed in a net pen for three days prior to release strongly suggests the benefits of release after acclimation; all 10 of these reached the Willamette Falls area.

Smolting Physiology Correlated with Migratory Behavior

The means of Na^+/K^+ gill ATPase activity in fish from hatchery raceways varied between about 5 and 22 μ Pi/mg protein/hr. In 1991 we collected hatchery smolts in the river up to 35 days after release and these showed a generally increased ATPase activity over time. In 1992 a sample of 10 fish from the three treatments electroshocked from the lower river near Willamette Falls 15-16 days after release had a mean gill ATPase activity of 9.9 μ Pi/mg protein/hr., not significantly higher than ATPase in hatchery fish. In 1993 were unsuccessful in

capturing sufficient fish by eiectroshocking to provide a valid sample for **ATPase** analysis.

Our sampling of smolts at the Sullivan evaluator provides a more **robust data** set of **ATPase** collected over several weeks. We must exercise caution, however, in equating collection date with arrival date for fish are known to reside in the raceway for several days (weeks) or more (see above). In 1992 we measured a significant elev ation in gill ATPase 21 to 32 days after release, suggesting readiness to enter sea water (Figure 57). The declines in ATPase 5 to 12 days after release, and 33 to 40 days may be owing to sampling variation. In 1993 we have samples collected at the Sullivan Plant up to 24 days after hatchery release. Gill ATPase steadily increased over time with all samples collected **at** the Sullivan evaluator being significantly higher than hatchery values (Figure 58); see also Beeman, et al., 1994; Zaug et al. 1994.

Radio Telemetry a Valid Tool

Radio telemetry has been used to study wildlife populations for decades. Recent miniaturization of components has produced radios small enough to implant in the stomachs of fish as small as 10 cm fork length (Snelling et al., 1994). During the present study as the technology improved, we used radios of gradually decreasing size. We have always been confident that our radio-tagged smolts behaved as did their untagged counterparts because their behavior **in** sequestering tanks is like untagged fish; they quickly integrate into the school when released into the raceway and they migrate downriver with untagged fish. Furthermore, laboratory studies suggest that the stress response mounted by tagged fish is similar to that of sham-tagged animals (L. Davis and M. Beck, OCFRU, pers. comm.)

The installation of an effective evaluator at the PGE Sullivan Plant in 1992 revealed that the travel times of tagged and untagged migrants were similar. This is our strongest evidence that tagged fish behave as their untagged counterparts.

Telemetry techniques have progressed from manually monitoring a few radios to remotely monitoring many. Manual techniques accumulate **precise** and relatively unambigu ous data, whereas remote monitoring approaches **a** more statistically acceptable sample size. Presently the size of juvenile fish tags precludes the incorporation of pulse-coding technology for relatively unambiguous detection of dozens of tags remotely. In 1993 we partly overcame this problem by sorting data by beats per minute, thus filtering noise from real signals.

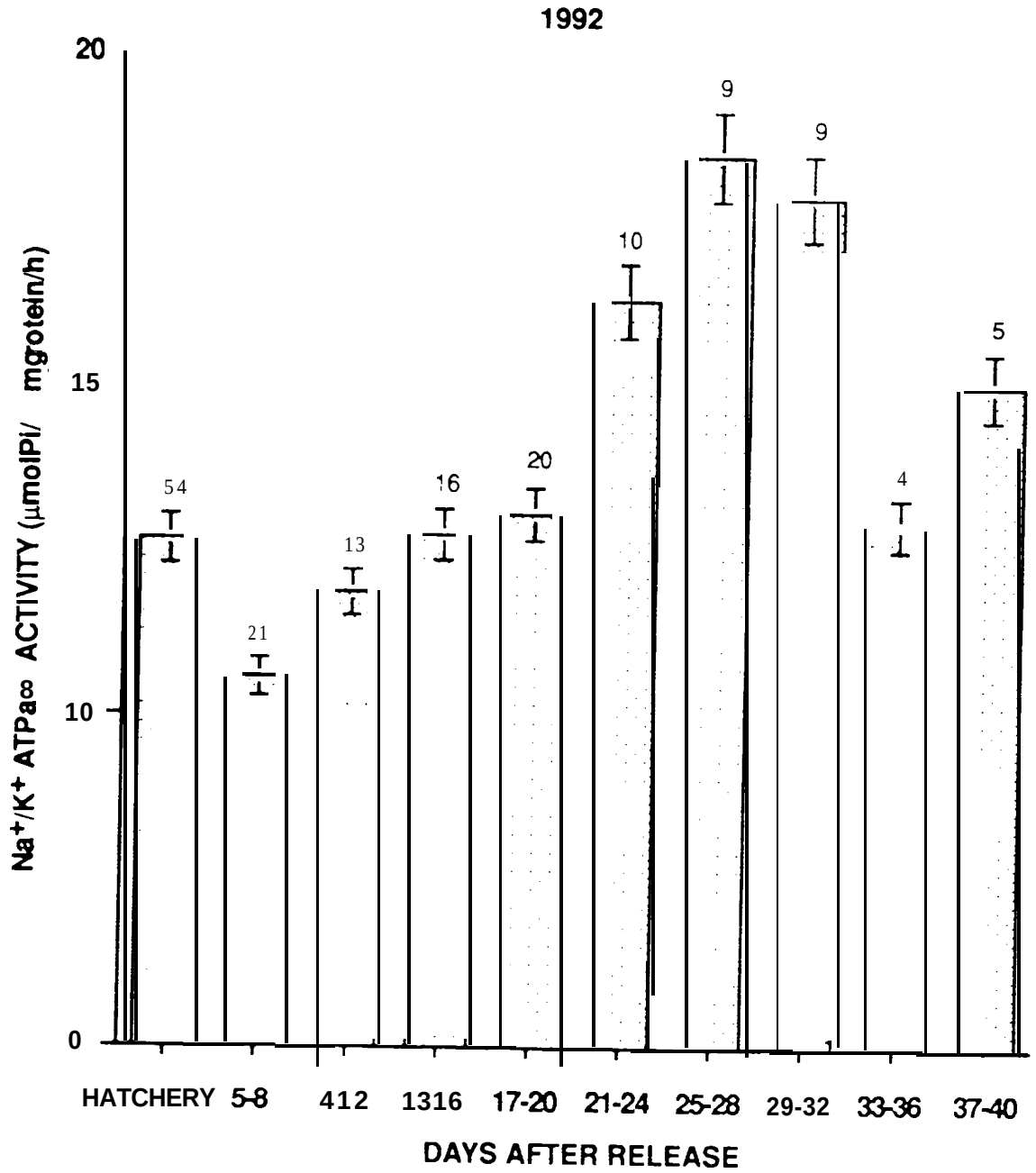


Figure 57. Mean sodium/potassium gill ATPase from juvenile spring chinook salmon collected at Willamette Falls (PGE Sullivan Evaluator) over the course of the 1992 outmigration compared with hatchery values. Standard error bars shown.

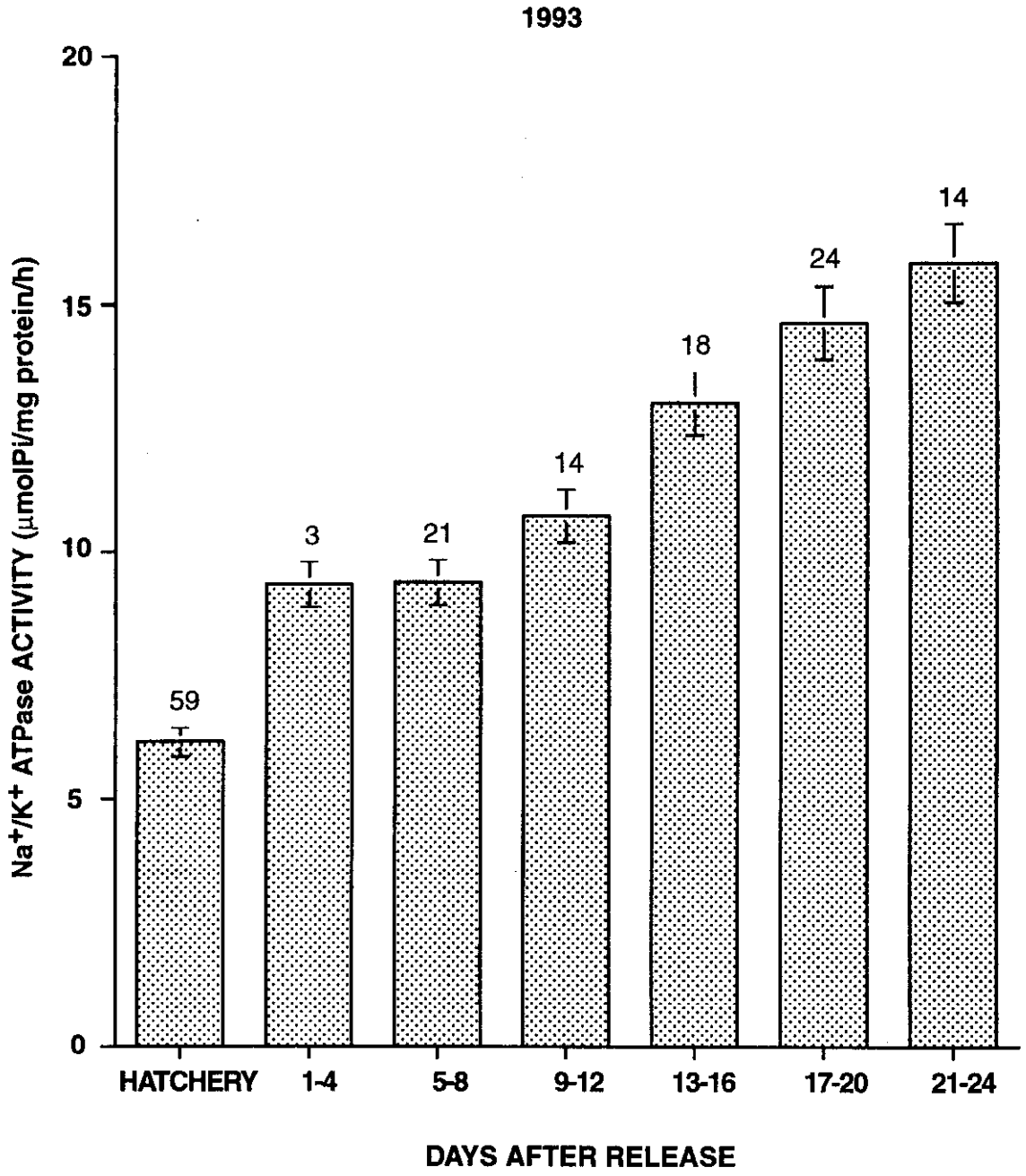


Figure 58. Mean Na^+/K^+ gill ATPase from juvenile spring chinook salmon collected at Willamette Falls (PGE Sullivan Evaluator) over the course of the 1993 outmigration compared with hatchery values. Standard error bars shown.

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Lastly several research assistants and numerous graduate assistants were involved in this study for a year or more. The research assistants include: Marcus Beck, Sean Ewing, Dawn Seward, Denise Kelsey, Brian Behle, Scott Evans, Nader Sidholm, Troy Goby, Dave Hart, and Jason Overby. Other Oregon Cooperative Fishery Research C-nit staff and students who assisted us include: Cameron Sharpe, Dan Farnsworth, Choo Guan Yeoh, Iris Knobel, Teri Tufts, Lisa Burtis, Heather Stanley, and Dr. Marty Fitzpatrick.

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Errata

Migratory Characteristics of Juvenile Spring Chinook Salmon in the Willamette River

page 2, paragraph 2, line 13:
change **coded wire** tags to read **coded wire tags (CWT)**

page 12, paragraph 1, line 1:
third the is transposed, change to read **the third**

page 24, paragraph 4, line 12:
end line with comma (,), not period (.)

page 29, paragraph 6, lines 2/3:
change (two each standard and triple density treatments, and five each from third Michigan treatments) to read **(two from the standard treatment and five each from triple density and third Michigan treatments)**

page 34, paragraph 5, line 1:
change individuals to read **individual**

page 78, Figure 43:
X axis label should read **DAYS AFTER RELEASE** as in Figure 42
cutline, line **3 change indicate** to read **indicated**
cutline, line 5 change **below** to read **above**

page 80, Figure 44 :
X axis label should read **DAYS AFTER RELEASE as in** Figure 42
cutline, line **3 change indicate** to read **indicated**
cutline, line 5 change **below** to read **above**