Study of Disease and Physiology in the 1980 Homing Study Hatchery Stocks– A Supplement to: "Imprinting Salmon and Steelhead Trout for Homing, 1980 by Slatick, Gilbreath, and Walch"

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

The National Marine Fisheries Service (NMFS), under contract to the Bonneville Power Administration, has conducted research on imprinting salmon and steelhead for homing (Slatick et al. 1979, 1980; Novotny and Zaugg 1979, 1981). This supplement completes a 3-year study to determine the status of fish health and certain physiological functions that might affect imprinting and homing in salmonids. The field work was begun by the authors in 1978 and concluded in 1980.

In 1980, we examined random samples of normal populations of homing test fish at the hatcheries at frequent intervals to determine their general health and physiological readiness to migrate, but did not conduct seawater challenge tests as in previous years. In 1978 and 1979, we were unable to sample at frequent intervals, but we did determine the survival of samples of test fish maintained in marine net-pens after release from the hatcheries. The number of hatcheries and stocks involved in the 1980 study was about double that of 1978 or 1979 (Table 1).

Data collected from random samples were as follows:

1. Physiology.

Gill Na^+-K^+ ATPase. Abnormally low values could be indications that the fish were either in pre- or post-smolting condition, or had been stressed in some way.

Plasma electrolytes. Lower than normal values of Na^+ or Cl^- could indicate immediate problems of osmoregulation when the fish were introduced to seawater; higher values may indicate some dehydration due to stress. Increases in levels of K^+ can indicate kidney failure or nitrogen supersaturation stresses.

Table 1.--Hatcheries and stock sampled in the 1980 homing studies.

Hatchery	Species	Date sampled	Pond no.	Date released	Histopathology tag no.
Dworshak	Steelhead	03/04/80	59	04/17/80	7061 to 7120
Dworshak	Steelhead	03/18/80	61		-- --
Dworshak	Steelhead	04/01/80	61		73 to 7420
Dworshak	Steelhead	04/15/80	61	04/17/80	-- --
Dworshak	Steelhead	04/29/80	--	(Held over in the	7661 to 7720
Dworshak	Steelhead	05/13/80	--	hatchery for post	-- --
Dworshak	Steelhead	06/04/80	--	release sampling)	-- --
Tucannon	Steelhead	03/07/80	01		-- --
Tucannon	Steelhead	03/07/80	04		-- --
Tucannon	Steelhead	03/07/80	02		-- --
Tucannon	Steelhead	03/21/80	01		-- --
Tucannon	Steelhead	03/21/80	04		-- --
Tucannon	Steelhead	03/21/80	02		-- --
Tucannon	Steelhead	04/04/80	01		7541 to 7560
Tucannon	Steelhead	04/04/80	04		7561 to 7580
Tucannon	Steelhead	04/04/80	02		7581 to 7600
Tucannon	Steelhead	04/10/80	01	04/08/80	-- --
Tucannon	Steelhead	04/10/80	02		-- --
Tucannon	Steelhead	04/10/80	04		-- --
Tucannon	Steelhead	04/18/80	04		-- --
Tucannon	Steelhead	04/18/80	02		-- --
Tucannon	Steelhead	05/02/80	04		-- --
Tucannon	Steelhead	05/02/80	02		-- --

Table 1.--Continued

Hatchery	Species	Date sampled	Pond no.	Date released	Histopathology tag no.
Tucannon	Steelhead	05/07/80	04	05/08/80	7781 to 7810
Tucannon	Steelhead	05/07/80	02		7811 to 7840
Tucannon	Steelhead	05/16/80	02		-- --
Tucannon	Steelhead	05/30/80	02		-- --
Tucannon	Steelhead	06/06/80	02		-- --
Tucannon	Steelhead	06/12/80	02	06/12/80	7841 to 7900
Leavenworth	Spring chinook	11/01/79	46	Fall marked fish (sampled in fall)	-- --
Leavenworth	Spring chinook	11/14/79	06	Spring marked fish (sampled in fall)	-- --
Leavenworth	Spring chinook	03/03/80	17		7001 to 7060
Leavenworth	Spring chinook	03/17/80	17		-- --
Leavenworth	Spring chinook	03/31/80	03	04/24-05/01/80	7301 to 7360
Leavenworth	Spring chinook	04/14/80	17		-- --
Leavenworth	Spring chinook	04/23/80	CH	04/24-05/01/80 (Released in channel)	-- --
Leavenworth	Spring chinook	04/23/80	46	04/24-05/01/80	-- --
Leavenworth	Spring chinook	04/23/80	17	04/24-05/01/80	-- --
Leavenworth	Spring chinook	04/23/80	CL	04/24-05/01/80 (Control held in channel 48 h)	-- --
Leavenworth	Spring chinook	04/28/80	15	(Held over for	7601 to 7660
Leavenworth	Spring chinook	05/12/80	15	post-release	-- --
Leavenworth	Spring chinook	05/29/80	15	sampling)	-- --
Leavenworth	Spring chinook	06/17/80	15		-- --
Kooskia	Spring chinook	03/05/80	10		7121 to 7180
Kooskia	Spring chinook	03/19/80	10		-- --
Kooskia	Spring chinook	04/02/80	10	04/16/80	7421 to 7480
Kooskia	Spring chinook	04/16/80	07	04/23-05/05/80	-- --

Table 1.--Continued

Hatchery	Species	Date sampled	Pond no.	Date released	Histopathology tag no.
Kooskia	Spring chinook	04/30/80	07	(Held over for	7721 to 7780
Tucannon	Steelhead	05/07/80	07	post-release	-- --
Kooskia	Spring chinook	06/05/80	07	sampling)	-- --
Rapid River	Spring chinook	03/06/80	01		7181 to 7240
Rapid River	Spring chinook	03/20/80	01		-- --
Rapid River	Spring chinook	04/03/80	01		7481 to 7540
Rapid River	Spring chinook	04/17/80	01	04/15/80	-- --
Rapid River	Spring chinook	05/01/80	01	(Held over in outside tanks for	-- --
Rapid River	Spring chinook	05/15/80	01	post-release sampling)	-- --
Carson	Spring chinook	12/13/79	--		-- --
Carson	Spring chinook	03/04/80	31		8051 to 8108
Carson	Spring chinook	04/04/80	31		8289 to 8349
Carson	Spring chinook	04/17/80	31		8501 to 8560
Carson	Spring chinook	05/12/80	31	05/12-05/15/80	8861 to 8920
Willard	Coho	12/12/79	--	Fall marked group	-- --
Willard	Coho	03/05/80	25		8109 to 8168
Willard	Coho	04/02/80	25		8229 to 8288
Willard	Coho	05/20/80	50	05/14-05/25/80	8661 to 8782
Spring Creek	Fall chinook	03/10/80	20		8169 to 8228
Spring Creek	Fall chinook	04/10/80	35		8351 to 8400
Spring Creek	Fall chinook	04/10/80	35		-- to --
Spring Creek	Fall chinook	05/08/80	22	05/09-05/19/80	8801 to 8860
Big Creek	Fall chinook	04/08/80	22		8401 to 8500
Big Creek	Fall chinook	04/23/80	22		8601 to 8660
Big Creek	Fall chinook	05/06/80	22		8701 to 8760

Table 1.--Continued

Hatchery	Species	Date sampled	Pond no.	Date released	Histopathology tag no.
Big Creek	Fall chinook	05/13/80	22	05/12-05/23/80	8921 to 8980
Hagerman	Fall chinook	06/02/80	11	06/03-06/05/80	-- --

Hematocrits and hemoglobins. Values below or above normal ranges usually indicate anemia or dehydration, respectively, which can reflect nutritional status, disease, or physiological changes.

2. Fish health.

The incidence of diseases during freshwater rearing, as reported in hatchery records describing the treatment of fish were examined.

Fish were examined for subclinical bacterial kidney disease (BKD) using an indirect fluorescent antibody technique (IFAT). Viral assays were not conducted in 1980.

Histological determinations of significant lesions or abnormalities in tissue from gills, eyes, and olfactory sacs were undertaken.

These surveys were conducted to provide a documentation of the health and physiological (smolt) condition of populations of fish involved in the tests, especially at the time of imprinting and release. When marked adult fish return, data analyzed from the health and physiology surveys should provide us with information that would indicate any adverse influence on survival.

METHODS AND MATERIALS

Sampling Fish in the Hatcheries

The method of sampling fish from hatchery stocks for health profiles was based on a combination of statistics and economics. Random sampling from populations ranging as high as 100,000 or more has shown that a disease incidence of 5% or greater can be detected with a sample of 60 fish (Ossiander and Wedemeyer 1973). Health survey samples of 60 fish were taken at the hatcheries.

Sampling of fish for health profiles began the first week in March 1980 and ended the second week of June 1980. A mobile laboratory was used to sample upper river hatcheries every 2 weeks. A similar procedure was used by our Willard Laboratory staff at the lower river hatcheries. All of the required samples were collected and completely or partially processed on site.

Each fish and each of the assorted samples taken were assigned a unique number for identification and data processing.

Blood Sample Collection

Fish were lightly anesthetized in an aerated 1:20,000 solution of MS-222 in groups of 10 to 15 fish. In the larger fish, blood was sampled from the caudal arch with a 1-cc ammonium heparinized syringe and a 25-gauge hypodermic needle. In small fish, blood was collected in ammonium heparinized capillary tubes after severing the caudal peduncle. Subsamples of blood taken for hematocrits (packed cell volume) were collected in microhematocrit tubes and centrifuged for 3 minutes in a Clay-Adams Autocrit II[1/] (Snieszko 1960). Subsamples of blood for hemoglobin determination were either read directly with an A-O hemoglobinometer, or collected in 20 ul capillary tubes and determined colorimetrically (Bauer 1970).

Plasma Electrolytes

Subsamples of blood were centrifuged in plastic serum vials, and the supernatant plasma was drawn off by disposable pipette, dispensed into plastic vials, sealed, and held frozen until they were shipped to a private

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1/ Reference to a trade name does not imply endorsement by the National Marine Fisheries Service.

laboratory for analysis. Plasma sodium and potassium values were determined by atomic absorption spectrometry and chlorides with a chloridometer. Before analysis, each plasma sample was ranked into four increasing levels of hemolysis.

Gill Na^{+}-K^{+} ATPase

During 1980, selected stocks of coho, fall, and spring chinook salmon and steelhead trout at state and federal hatcheries in the Columbia River drainage were monitored for changes in gill Na^{+}-K^{+} ATPase to estimate the state of smoltification at release.

At approximately 2-week intervals during the spring and summer of 1980, 30 fish were removed by dip net for Na^{+}-K^{+} ATPase analysis from representative ponds or raceways at hatcheries that participated in the homing studies (see Table 1). Ten groups of three fish each were anesthesized at each sampling. After fork lengths were determined and blood samples taken, approximately equal quantities of gill filaments were removed from gill arches of each of the three fish in the group (total weight of gill filaments, 0.1 to 0.2 g), snap-frozen in liquid nitrogen, and processed as described by Novotny and Zaugg (1979). Fall chinook salmon from the Hagerman National Fish Hatchery (NFH) were not sampled as extensively as the others, but a gill Na^{+}-K^{+} ATPase profile was obtained.

Life History of Hatchery Juveniles

Husbandry techniques, disease, and environmental history may have deleterious effects on fish health and smolt quality (Wedemeyer et al. 1980; Folmar and Dickhoff 1979, 1981). Many chemotherapeutic compounds used in the treatment of parasitic and bacterial diseases of fish may affect smoltification (Lorz and McPherson 1976), and subclinical infections may be exacerbated by the stress of seawater entry.

Information in Table 2 was obtained from hatchery management and is self-explanatory. Where information was not obtained, the entries have been left blank.

Histopathology

Sixty individually numbered fish of each test group were fixed in 10% buffered Formalin and submitted to Bio-Med Research Laboratories. Gill, eye, and olfactory tissues were sectioned, appropriately stained, and examined for any pathologic lesions or abnormalities. All lesions were evaluated as described in Novotny and Zaugg (1979, 1981)[2/].

Bacteriological Assays

The sensitive and highly specific indirect fluorescent antibody technique (IFAT) was used to diagnose latent Bacterial Kidney Disease (BKD) in hatchery populations.

Fish were opened ventrally and the kidney exposed. Thin smears of anterior and posterior kidney tissue were made on multi-spot slides after piercing the kidney with a sterile inoculation loop. Slides were air-dried and fixed in reagent grade acetone for 10 minutes. The acetone fixed slides were stored at -20°C until examined. Prior to the sampling season, positive control slides were prepared and stored in the same manner using a clean kidney lesion in a spring chinook salmon from Carson NFH that was tested and confirmed to have high numbers of BKD organisms.

[2/] A copy of the complete veterinary pathologist's report for the 1980 studies can be obtained by written request from the Director, Coastal Zone and Estuarine Studies Division, NWAFC, NMFS, 2725 Montlake Boulevard East, Seattle, Washington 98112.

Table 2.--Available disease and life history data of homing study hatchery juveniles

Hatchery	Stock	Agency[a]	Species	Date of egg take	Date ponded	Feed[b]	Water source
DWORSHAK NATIONAL	Dworshak	USFWS	Steelhead	4/10/79	7/1/79	OMP	System III re-use (conditioned N. Fork Clearwater River)
TUCANNON	Skamania	WDG	Steelhead	March, 1978	—	DRY & OMP	River
LEAVENWORTH NATIONAL	Leavenworth	USFWS	Spring chinook	8/10-8/30, 1978	3/27/79	OMP	Well & river
KOOSKIA NATIONAL	Carson & Kooskia	USFWS	Spring chinook	August, 1978	--	OMP & DRY	Well & river
RAPID RIVER	Rapid River	IDFG	Spring chinook	8/10-9/11, 1978	Raceways 11/27/78, Earthen ponds 5/15/79	OMP	River
CARSON NATIONAL	Carson	USFWS	Spring chinook	8/21-8/28, 1978	1/18/79	OMP & DRY	Springs, creek, river
WILLARD NATIONAL	Little White salmon	USFWS	Coho	1978	--	OMP	Well & river
SPRING CREEK NATIONAL	Spring Creek	USFWS	Fall chinook	9/17-9/29, 1979	12/10- to 12/18/79	OMP & DRY	Springs
BIG CREEK	Big Creek	ODFW	Fall chinook	9/20-10/4, 1979	1/3- to 1/18/80	OMP	Big Creek
HAGEMAN NATIONAL	Snake River	USFWS	Fall chinook	Sept. 1979 (Tucannon Hatchery)	Hagerman	OMP	Spring

a/ WDG--- Washington Department of Game
USFWS- United States Fish & Wildlife Service
ODFW-- Oregon Department of Fish and Wildlife
IDFG-- Idaho Department of Fish & Game

b/ OMP--- Oregon Moist Pellets

c/ BGD--Bacterial Gill Disease
BKD--Bacterial Kidney Disease
ERM--Enteric Red Mouth
ICH--Ichthyophthirius

d/ TM50-Dietary Oxytetracycline

Table 2.--continued

Water temp-°F	Percent mortality (all causes)	Size at release (no/lb)	Date released (1980)	Diseases[c]	Treatments
50-60 for rearing; 43-48 for conditioning for release	35% before ponding; 5% after ponding.	8.6	4/22-4/30	N2 supersaturation (early) Whitespot (early)"ich" Epistylis	--
--	--	--	May	Epistylis	Formalin & malachite green
32-63	5.2%	17.6	4/24-4/30	BGD, BKD	--
--	--	--	April	BKD	--
34-60	13% to ponding	15.0	207,000 Sept 1979; 2.6 million March-April 1980.	BGD	3% salt/bath & 1/2 ppm/ malachite/ green dips.
44-51	32%	23.3	4/28-5/16	BKD & Costiasis	TM50; sulfamerazine; formalin.
--	--	--	--	--	--
46-52	24%	from 1140 to 19	10 releases 12/19/79 to to 8/7/80	ERM; Finrot; gill amoeba	Formalin; Roccol; TM50.
39-50	2%	77.5	5/13/80	None	None
58	--	--	Early June	--	--

The IFAT procedure used in this study for BKD, originally described by Bullock and Stuckey (1975) and later modified by G. W. Camenisch (unpublished report) of the U.S. Fish and Wildlife Service (FWS), Eastern Fish Disease Laboratory, is described in Novotny and Zaugg (1979).

RESULTS AND DISCUSSION OF STEELHEAD SURVEYS

Dworshak National Fish Hatchery

General

In the early part of the season, water re-use at the hatchery was about 90%, but the temperature was held down. Sampling from the ponds began in early March and continued until release in mid-April. At that time, approximately 600 fish were transferred to indoor circular tanks and held for additional sampling until June. Hatchery personnel fed and maintained these fish and tried to provide at least 12 hours/day of light.

Table 3 summarizes major data (means and standard deviations) collected during each sampling period in 1980 for Dworshak NFH steelhead (histopathology and BKD summaries are presented elsewhere).

We noted a visible erosion of gill filaments in many fish on the second trip (18 March), but almost none on the third trip (1 April). These changes may be related to increases and decreases in water temperature which are shown in Figure 1[3/].

Average fork lengths of both control (163 mm) and test release (167 mm) groups (Table 3) were much smaller than release groups sampled in 1978 (193 mm). This probably can be attributed to the lower water temperature in 1980.

[3/] Summary profiles are presented as "Number of Days Post 1 January 1980" for convenience of computing and plotting. Whenever possible, the sampling periods are presented next to the data points (see Table 1 for the dates of the sampling periods). Appendix A contains a cross reference chart for converting number of days post 1 January 1980 to calender date.

Table 3.--Summary data for the spring (1980) sampling of the Dworshak Hatchery steelhead (n=60), with means, standard deviations ( ), and ranges.

Item	Period 1	2	3	4*	5**	6	7
Date	4 March	18 March	1 April	15 April	29 April	13 May	4 June
Days>Jal a/	63	77	91	105	119	133	154
Temp.-°C b/	8.3	9.7	6.0	7.5	7.5	10.0	10.0
Avg. Fk Ln c/	158.5	167.1	157.1	162.6	166.9	172.3	178.6
	(21.3)	(18.1)	(24.6)	(21.2)	(23.0)	(22.5)	(21.1)
(Range)	115-207	117-212	115-213	130-210	114-206	122-214	125-228
Avg. ATP Fk Ln d/	165.9	164.3	157.7	168.1	163.3	173.1	178.6
	(18.5)	(20.1)	(25.0)	(20.0)	(25.4)	(25.3)	(22.7)
(Range)	147-182	128-181	129-190	141-198	119-198	137-202	138-207
Avg. ATP e/	6.28	5.07	6.27	7.48	8.58	7.16	6.92
	(0.81)	(0.53)	(1.23)	(7.48)	(8.58)	(1.42)	(1.26)
(Range)	4.9-7.5	4.1-6.0	4.6-8.5	6.1-8.6	6.4-10.6	5.2-9.2	4.3-8.4
Avg. Hct f/	48.7	48.1	58.8	48.6	52.7	43.0	47.8
	(6.15)	(7.61)	(5.21)	(5.85)	(7.40)	(6.42)	(5.37)
(Range)	35-63	29-66	41-72	34-62	35-67	26-56	36-58
Avg. Hb g/	8.6	8.2	10.9	8.5	9.1	7.7	8.1
	(1.34)	(1.26)	(1.05)	(1.50)	(1.32)	(1.26)	(1.02)
(Range)	6.0-12.0	6.0-11.0	8.4-12.9	5.0-12.3	6.8-12.6	4.3-10.0	6.0-10.3
Avg. MCHC h/	17.6	17.3	18.6	17.6	17.3	18.0	17.1
	(1.70)	(1.55)	(1.55)	(2.60)	(1.75)	(2.14)	(1.46)
(Range)	11.1-20.6	13.8-21.4	13.5-22.2	12.3-27.3	13.7-23.1	9.6-23.7	12.5-21.8
Avg. Na^+ i/	154.2	146.4	146.5	157.2	144.3	149.9	155.8
	(10.9)	(9.0)	(6.8)	(9.5)	(11.5)	(16.1)	(5.6)
(Range)	120-176	125-165	134-162	125-173	123-162	73-200	133-169
Avg. K^+ j/	1.70	0.80	1.50	0.60	0.60	1.10	0.60
	(0.96)	(0.32)	(0.63)	(8.96)	(0.18)	(1.07)	(0.31)
(Range)	0.36-4.50	0.45-1.72	0.51-2.50	0.25-1.98	0.37-1.13	0.34-4.80	0.20-1.75
Avg. Cl^- k/	129.1	123.9	128.6	130.0	114.2	132.3	130.6
	(11.1)	(14.7)	(7.2)	(9.0)	(9.1)	(10.0)	(6.5)
(Range)	92-150	87-154	116-141	96-146	99-135	97-162	117-144
Na^+/Cl^- l/	1.20	1.20	1.14	1.21	1.27	1.14	1.20
	(0.12)	(0.13)	(0.06)	(0.06)	(0.08)	(0.07)	(0.07)
(Range)	1.00-1.68	0.97-1.51	1.06-1.29	1.01-1.40	1.17-1.54	1.02-1.31	1.06-1.38

* Normal (control) release group
** Test release group
a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp. -°C: Water temperature (in °C) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. ATP: The average gill ATPase levels for that period (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour).
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodiums to chlorides for that period, averaged.

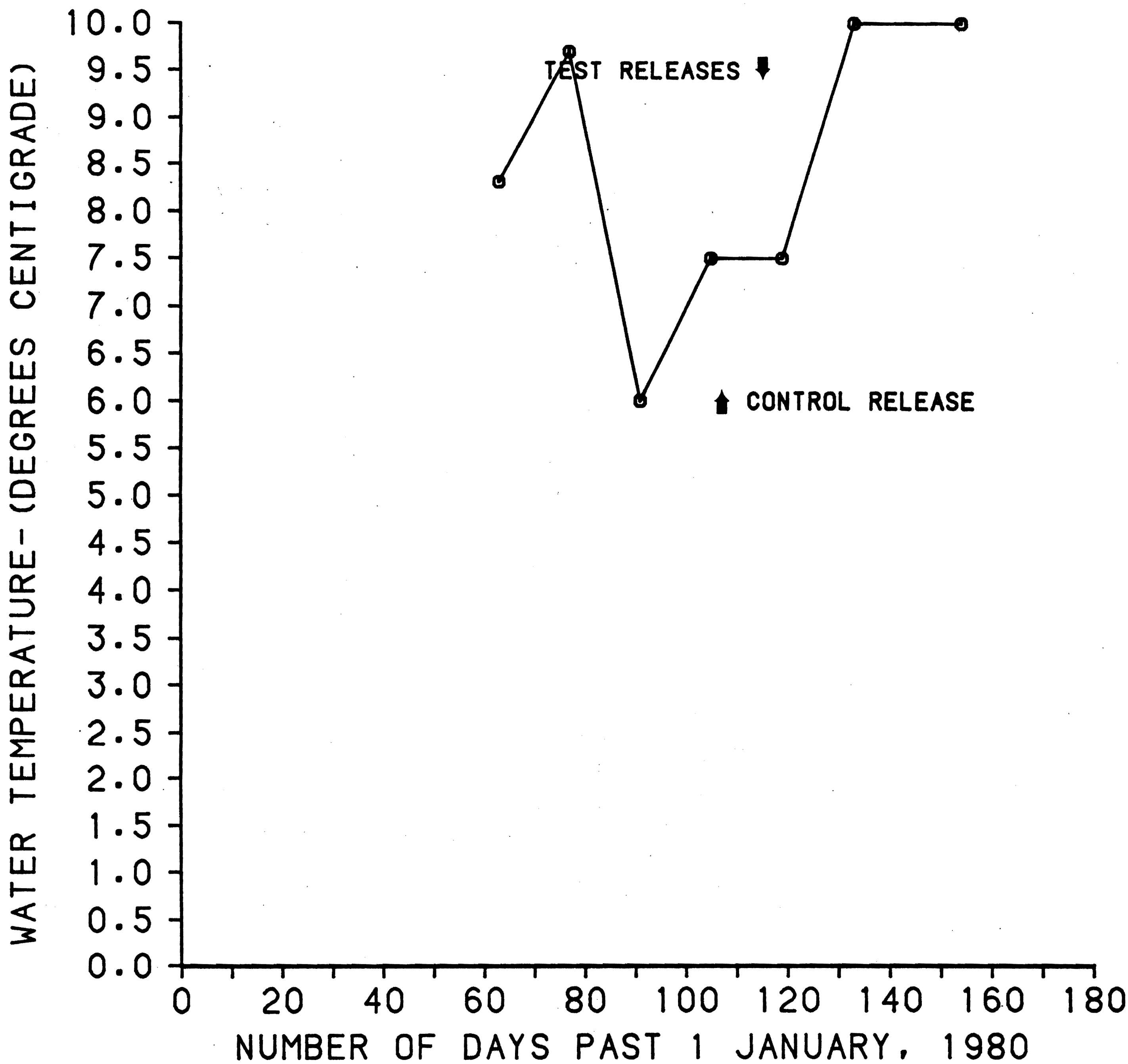


Figure 1.--Water temperatures at Dworshak NFH during spring 1980.

Gill Na^{+}-K^{+} ATPase

Since the phenomenon of elevation in gill Na^{+}-K^{+} ATPase activity was first reported to be associated with parr-smolt transformation in steelhead (Zaugg and Wagner 1973) and in coho salmon (Zaugg and McLain 1970), numerous experiments have been conducted to verify these results and extend observations to other species. As a result, it has been conclusively shown that the rise in gill Na^{+}-K^{+} ATPase activity is one of the physiological changes which occur at the time of parr-smolt transformation.

In 1978, the mean gill Na^{+}-K^{+} ATPase activity was 5.0 ($\pm$1.1) u moles Pi/mg protein/hour on 24 April. The activity measured in 1980 (Table 3) indicates a peak on 29 April (5th period). However, this peak activity (average 8.6 $\pm$ 1.5) is far below expected values for highly developed smolts. Transfer of fish at this release time from the raceway to an inside holding tank for further sampling resulted in significant environmental changes, including an increase in water temperature from 7.5° to 10°C. That this change in holding conditions caused a reversal in Na^{+}-K^{+} ATPase development is quite likely. Those fish transported and released undoubtedly experienced continuing increases in gill Na^{+}-K^{+} ATPase activity as they migrated seaward. Nevertheless, fish held under the conditions used for extended sampling showed decreased activity after 29 April, thus producing a small peak on that date. We can state that the migration-transport group was released during a period of rising gill Na^{+}-K^{+} ATPase activity, but that maximal levels had not yet been achieved. The range of activity in 1978 was from 3.5 to 7.2, but in 1980 during the same period the average was from 6.4 to 10.6. Higher Na^+-K^+ ATPase values in 1980 during the late April period may be due to a cooler temperature regime. In 1978, water temperatures ranged from 13° to 15°C, and the upper limit which will permit rising gill Na^+-K^+ ATPase activities in steelhead is about 12°C (Zaugg et al. 1972). The migration-transport group was released as gill Na^+-K^+ ATPase activity was rising, and the control group was released 17 April, just after the 4th sampling period.

We could find no significant correlations between the average gill Na^+-K^+ ATPase data and the averages of other data collected throughout the spring. When individual gill Na^+-K^+ ATPase activities from pooled 3-fish samples were compared with the average fork lengths of the pooled 3-fish samples, significantly higher correlations ($P = 0.001$; $P < 0.02$) were found only during the fourth and last sampling periods (Table 4). If smolting was initiated between the 4th and 5th periods as indicated by the Na^+-K^+ ATPase activity in Table 3, an approximate Na^+-K^+ ATPase index of smolting between those periods would be a value of 7.5. This would suggest that those steelhead larger than 168 mm were beginning to smolt (Figure 2).

On the basis of this information, approximately 38% of the Dworshak NFH steelhead would have started smolting in the 4th period (Figure 3).

Plasma Electrolytes

A compilation of data on rainbow trout by Miles and Smith (1968) and Hickman et al. (1964) suggests expected normal or near normal plasma electrolyte values in fresh water of 130 to 172 mEq (milliequivalents)/l for Na^+, 1.4 to 6.0 mEq/l for K^+, and 111 to 155 mEq/l of Cl^-.

Table 4.--Correlation coefficients between gill Na^{+}-K^{+} ATPase values for each sampling period, and the average fork lengths of the Dworshak Hatchery steelhead used to provide the gill samples in 1980 (3 fish/Na^{+}-K^{+} ATPase analysis: 30 fish/period).

Item	Period						
	1	2	3	4	5*	6*	7*
Correlation coeff.	-0.33	0.03	0.22	0.87	0.36	0.34	0.75
P (DF = 8)				<0.001		<0.02	

* Groups held inside the hatchery (in small tanks) for post-normal release sampling. Stresses of handling, confinement, and artificial light conditions may have affected these fish.

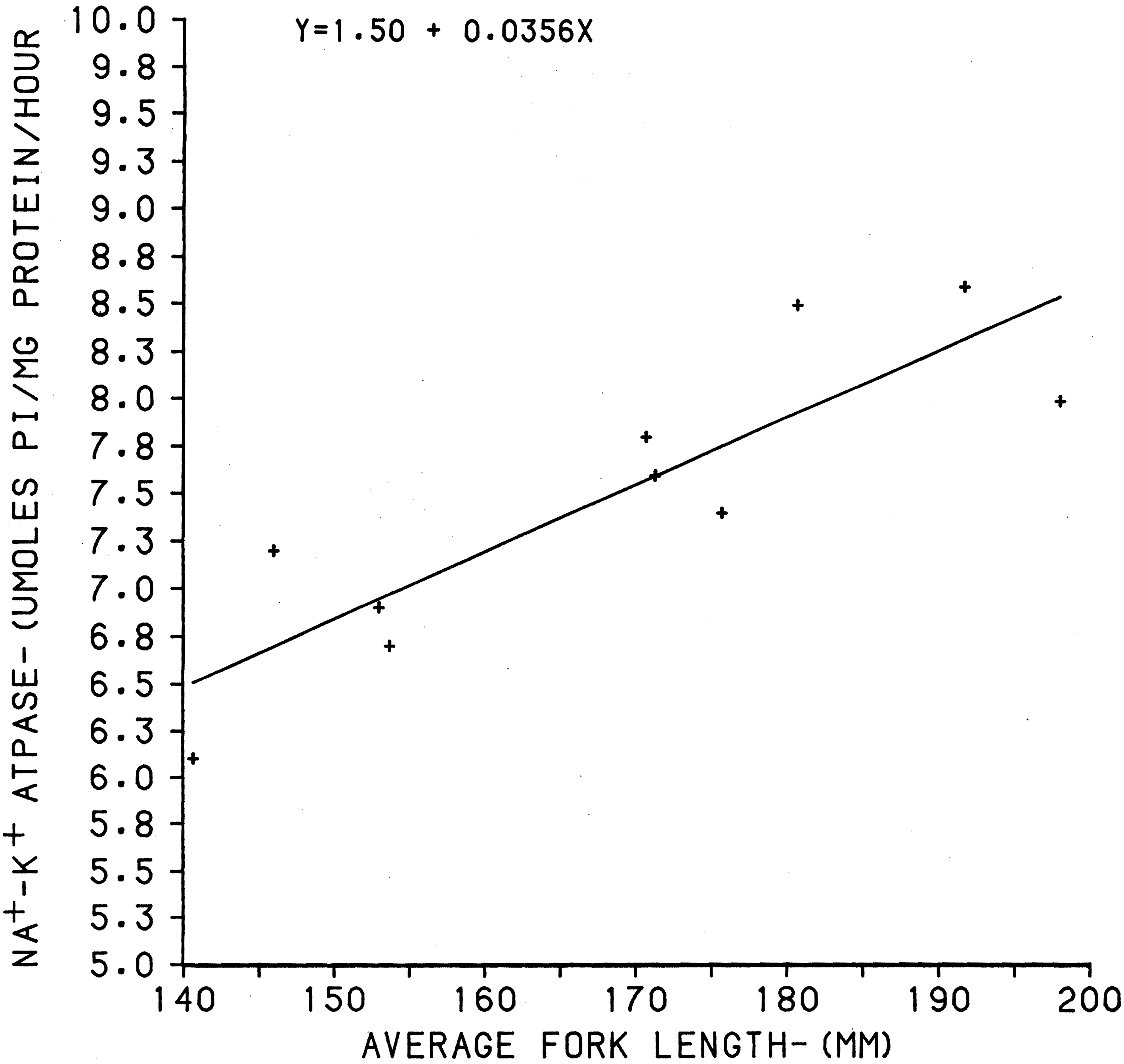


Figure 2.--Regression of gill Na^+-K^+ ATPase activity on average fork length in the 4th sampling period (3 fish pools for each Na^+-K^+ ATPase analysis) - 15 April 1980, Dworshak NFH steelhead. r = 0.87; P = 0.001.

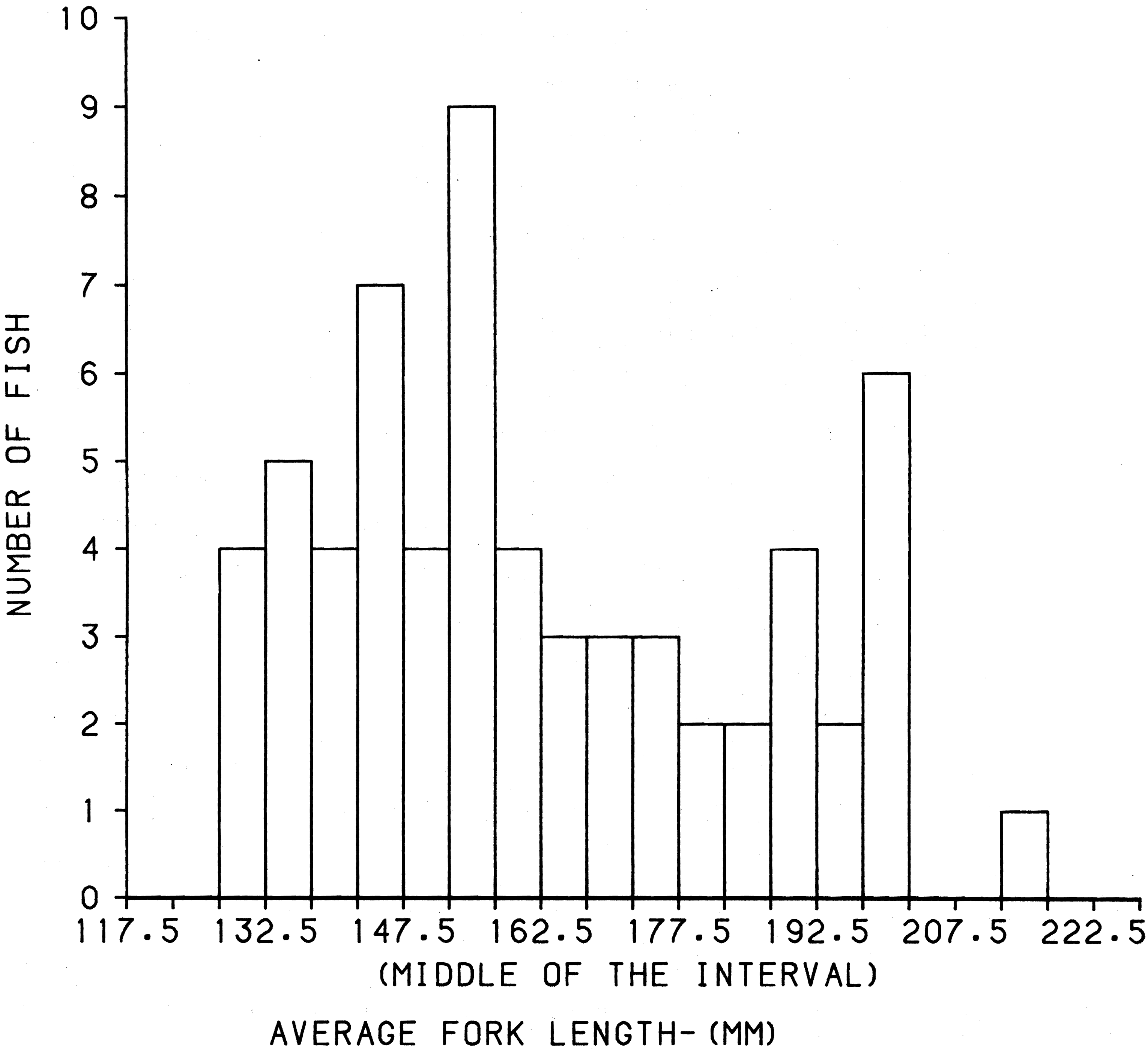


Figure 3.--Length-frequency histogram of steelhead sampled from Dworshak NFH in the 4th period.

Table 5 lists some known values for steelhead from available published literature, including data for the Dworshak NFH steelhead (Newcomb 1978). Newcomb's data are extensive, represent reasonably large sample sizes (15 to 25), and are probably good approximations of Columbia River steelhead.

Average plasma Na^+ values for Dworshak NFH steelhead throughout the season during 1980 were well within the previously published ranges (Table 3), but are below the mean value (166.4 mEq/l) of samples collected at release in 1978. Mean plasma Cl^- values (Table 3) are also well within the suggested range and the mean value at release in 1978 (133.3 mEq/l). The early fluctuations in plasma Na^+ (Table 3) may have been due to changes in water quality, but there is definitely a coincidental sharp decline in both plasma Na^+ and Cl^- between the 4th and 5th periods which is also coincidental, but inverse to a significant rise in gill Na^+-K^+ ATPase activity.

There were no significant correlations of plasma Na^+ or Cl^- or plasma Na^+/Cl^- ratios to fork lengths in any period. Correlations of plasma Na^+ to Cl^- gradually increased with each period, were highly significant ($P < 0.001$) from the 3rd to the 6th period, and reached a peak of $r = 0.69$-0.70 during the 4th and 5th periods (Table 6). Wedemeyer (1980) reports that a marked decline in plasma Cl^- can be expected in anadromous salmonids during smoltification and Houston (1959) reports the same for steelhead.

Mean plasma K^+ values were highly erratic throughout the sampling period, but the general trend was downward (Table 3). The fact that average plasma K^+ values during early 1980 were 1.7 mEq/l or less (lower range was 0.5 mEq/l), and in 1978 (Novotny and Zaugg 1979) were similarly

Table 5.--A summary of plasma Na^+, K^+, and Cl^- values in steelhead (from published sources).

Condition	Na^+	Cl^-	K^+	References
June-July (55 g fish)				
Laboratory tests				
Freshwater	$\bar{X}$ = 162	Range: 140-160	$\bar{X}$ = 6.0	Houston (1959)
Saltwater	$\bar{X}$ = 170	137-185		
March-May (13-15 cm fish)				
Laboratory tests				
Freshwater (range of mean values)	102-149	105-161		Conte and Wagner (1965)
Spring 1975				
Dworshak Harchery (at release)		$\bar{X}$ = 134.2 Range: 128-138		Newcomb (1978)
Captured at Little Goose Dam (downstream from Dworshak)		$\bar{X}$ = 134.2 Range: 128-141		
Laboratory tests (control groups-Spring)	Mean values range from: 159 to 169	133 to 138	2.6 to 4.3	Newcomb (1978)
	Individual values range from: 155 to 182	128 to 144	2.3 to 5.2	

Table 6.--Correlation coefficients between plasma Na^+ and Cl^- for each sampling period in 1980 for Dworshak NFH steelhead.

Item	Period 1	2	3	4	5	6	7
Correlation coeff.	0.377	0.454	0.587	0.687	0.696	0.607	0.158
P	<0.005	<0.001	<0.002	<0.001	<0.001	<0.001	n.s.

low ($\bar{x}$ = 1.0; sd = 0.8), suggests that plasma K^+ values reported by other researchers (Table 5) are high, or that a unique situation exists at Dworshak NFH.

There were no significant correlations between any plasma electrolyte measurements and water temperature.

Hematology

There are considerable hematological data in the literature for rainbow trout, less for steelhead trout. From data summarized in Table 7, it is possible to estimate lower limits of mean hematocrits of 30% and lower mean hemoglobin values of 6 for healthy steelhead. Upper levels are more difficult to define. Snieszko (1960) reports mean hematocrits of 53% and mean hemoglobin levels of 8.7 g/dl of blood in rainbow trout of a size comparable to large steelhead smolts. Although our values for Dworshak NFH steelhead (Table 3) were much closer to Snieszko's, Newcomb (1978) reported mean hematocrit levels in steelhead similar to that found by other researchers for rainbow trout (Table 7). A number of authors (McCarthy et al. 1973; Wedemeyer and Nelson 1975; Wedemeyer and Yasutake 1977) repeatedly suggest that hematocrit levels of clinically healthy rainbow trout should be between 24 and 43%, with hemoglobins ranging from 5.4 to 9.3 g/100 ml blood, and these values will be used as the expected range for individual steelhead in this report.

Summarized hematological data for Dworshak NFH steelhead are presented in Table 3. Since we have spatial data for the 1980 hatchery samplings, we are including an analysis of the Mean Corpuscular (or cell) Hemoglobin Concentrations (MCHC) in this report. MCHC is the amount of hemoglobin (in g/dl) in the Packed Cell Volume (PCV, which is synonymous with the

Table 7.--A summary of hematocrit and hemoglobin values for rainbow and steelhead trout (from published sources).

Source of data	Hematocrit (%)	Hemoglobin (g/100 ml blood)	References
Rainbow trout	$\bar{X}$ = 31.6 S.D. = $\pm$ 0.3	$\bar{X}$ = 7.4 S.D. = $\pm$ 0.15	Houston and DeWilde (1968)
Rainbow trout	$\bar{X}$ = 28.2 to 31.7 (Individuals:) (11 to 44)	$\bar{X}$ = 6.5 to 7.7 (Individuals:) (2.2 to 13.0)	Barnhart (1969)
Rainbow trout (Kamloops strain)	$\bar{X}$ = 39.5 (30 to 49)	$\bar{X}$ = 7.5 (5.2 to 12.9)	McCarthy et al. (1973)
Rainbow trout (Shasta strain)	$\bar{X}$ - 34.1 (24 to 43)	$\bar{X}$ = 7.6 (5.4 to 9.3)	Wedemeyer & Yasutake (1977), Wedemeyer & Nelson (1975)
Rainbow trout (average 14.2 cm)	$\bar{X}$ = 45.3	--	Snieszko (1960)
(average 23.5 cm)	$\bar{X}$ = 53.0	$\bar{X}$ = 8.7	
Steelhead trout At Dworshak Hatchery (spring)	$\bar{X}$ = 40.3 (36 to 47)		
At Little Goose Dam (spring)	$\bar{X}$ = 35.6 (28 to 44)		Newcomb (1978)
Laboratory tests (spring)	$\bar{X}$ = 31 to 37.8 Individual range: 28 to 45		

hematocrit, Hct), and is calculated from the total hemoglobin (Hb) and hemotocrit (Hct) as:

$$\frac{\text{Hb (in g/dl)}}{\text{PCV (in ml/dl}} \text{ blood) x 100 = MCHC (g/dl)}$$

(Schalm 1975).

Steele (1978) reports that MCHC is a sensitive indicator of stress in fish, and that a sharp increase typically occurs under stressful conditions.

Average hematocrits and hemoglobins at the time of release in 1978 (20-25 April) were 52.4% and 11.3 g/dl blood, respectively. Similarly high values dominated the Dworshak NFH steelhead throughout the 1980 sampling periods (Table 3), and the largest percentage of samples to fall below any expected range was 3.3% (for Hb $\leq$ 5.4 g/dl blood) during the 6th period. The general trend for both Hct and Hb was a sharp early rise, followed by a downward trend after the 3rd period. All of the mean values were within suggested limits, but indicate that normal data for steelhead Hct and Hb may be significantly higher than for non-anadromous *Salmo gairdneri*. There were two sharp increases in MCHC (Table 3), both shortly after changes in environmental conditions (changing water supplies and habitat). MCHC values at release (Periods 4 and 5) appear to be normal.

Average Hct and average Hb were positively correlated ($r = 0.97$; $P < 0.001$, Figure 4). Hematocrits and hemoglobins were positively correlated throughout the sampling season ($P < 0.001$), with r values ranging from 0.580 to 0.850.

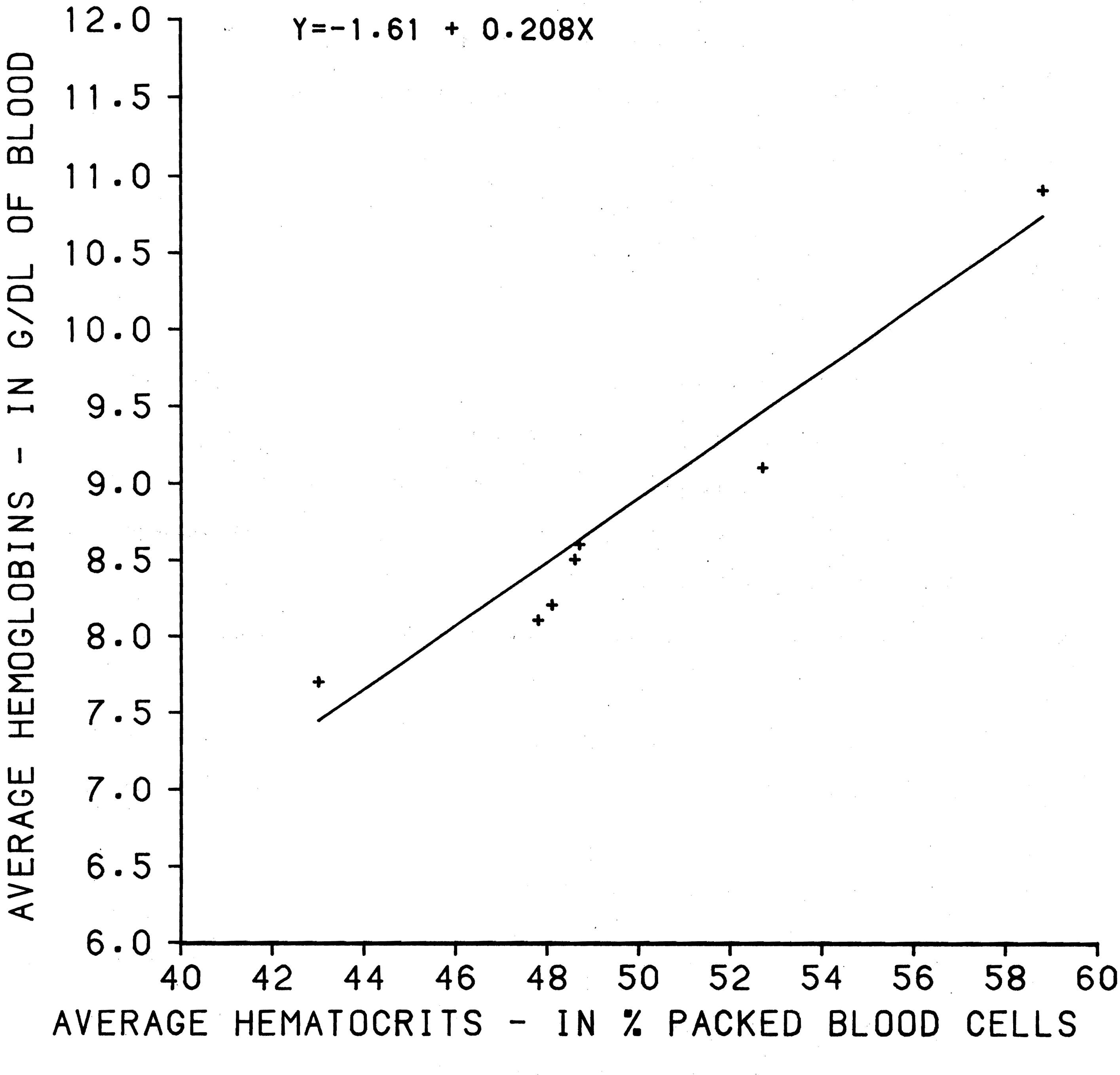


Figure 4.--Regression of the average hemoglobins on average hematocrits for the Dworshak NFH steelhead during spring 1980. $r = 0.972$; $P < 0.001$.

There were highly significant negative correlations between water temperature and average hematocrits ($r = 0.87$; $P < 0.020$) and average hemoglobin values ($r = 0.89$; $P < 0.010$) throughout the sampling periods (Figure 5). There were no significant correlations between average fish size and average Hct, Hb, or MCHC, nor between MCHC and water temperature or gill Na^{+}-K^{+} ATPase activity.

Clinical data on hematology throughout the sampling period indicated that the stock was in good health at the time of release.

IFAT-BKD

Specimens of Dworshak NFH steelhead from the first, third, and fifth sampling periods were examined for the presence of BKD organisms by the IFAT. The incidence and intensity of infection was light in most cases.

During the first period (3 March 1980), 7 out of 60 fish examined (11.7%) had BKD organisms in either the anterior or posterior kidney, and the level of intensity ranged from 1 to 5 organisms/150 microscopic fields. No BKD organisms were found in the third period samples, and only 2.7% of the samples were infected in the fifth period. Intensities of infection in samples from the latter period were much higher, ranging from 53 to 148 organisms/150 microscopic fields. Total infection for the 180 fish examined during the three periods was 5%, which is low.

Histopathology

A summary of the pathological conditions observed, their severity, and their frequency of occurrence is presented in Table 8. The severity is ranked as: I--recognizable (least severe), II--intermediate, and

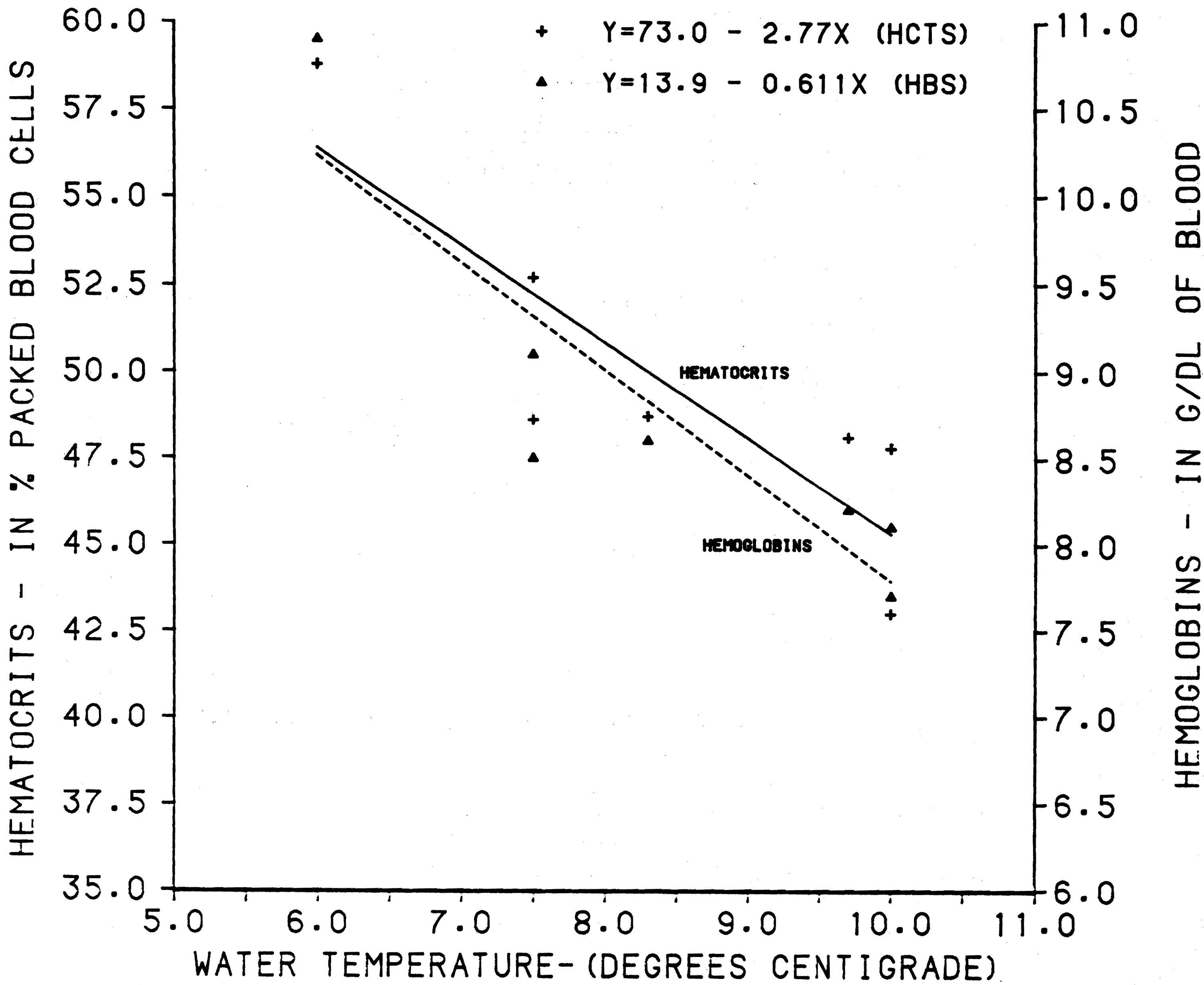


Figure 5.--Regressions of average hematocrits (x) and hemoglobins (^) of juvenile steelhead on water temperatures at Dworshak NFH during spring 1980. D.F. = 5. $r = -0.866$; $P < 0.20$ (hematocrits); $r = -0.892$; $P < 0.10$ (hemoglobins).

Table 8.--Pathological conditions observed in Dworshak Hatchery steelhead in 1980, and their percentage of incidence.[a/]

Organ and pathology	Incidence (%)											
	Period 1 (severity)[b/]				Period 2 (severity)				Period 5 (severity)			
	I	II	III	Total	I	II	III	Total	I	II	III	Total
Eye												
Skeletal muscle lesions	68.3	0	0	68.3	65.0	13.3	0	78.3	47.1	0	0	47.1
Gills												
Increased number of lymphocytes	60.0	25.0	0	85.0	25.0	66.7	6.7	98.3	51.7	36.7	0	88.4
Epithelial cell formation	45.0	33.3	6.7	85.0	0	33.3	66.7	100	36.7	41.7	16.7	95.1
Solitary basophilic organism	3.3	0	0	3.3	0	0	0	0	1.7	0	0	1.7
Vascular telangiectasis secondary lamellae	50.0	13.3	0	63.3	18.3	1.7	0	20.0	6.7	1.7	0	8.4
Acute focal hemmorhage	0	0	0	0	3.3	0	0	3.3	0	0	0	0
Bacteria present	0	0	0	0	3.3	0	0	3.3	1.7	0	0	1.7
Sporozoan parasite in secondary lamellae	0	0	0	0	0	0	0	0	0	1.7	0	1.7
Acute exudate	0	0	0	0	1.7	0	0	1.7	0	0	0	0
Olfactory sac												
Focal mononuclear cell infiltration	40.0	48.3	7.7	96.0	58.3	31.7	3.3	93.3	66.7	15.0	0	81.7

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of pathological lesions.

b/ I--recognizable (least severe); II--intermediate; III--severe.

III--severe (a composite summary for all hatcheries is presented in Table 9).

At or near release, Dworshak NFH steelhead were characterized by much lower incidences of gill parasites in 1980 than in 1978 (1.7 vs 28.3%). Incidence rates in eye lesions and other lesions of the gills were approximately the same. There was a marked decrease in miscellaneous gill lesions between the first sampling in March and the final release in late April (Table 9), which was apparently due to a decrease in the incidence of telangiectasis (basically capillary lesions) of the secondary lamellae (Table 8). There was a marked decline in severity of olfactory sac lesions (Table 8) as the sampling season progressed. Some of the decreases in incidence of tissue lesions may have been the result of a change from recycled to single pass water.

Hatchery records (Table 2) indicate that in the early culture phases (1979) there were some problems with nitrogen saturation, "whitespot" disease, "Ich," and epistylis. Mortality was estimated at 35% before ponding, but only 5% between ponding and release.

Summary

Serial sampling of the Dworshak NFH steelhead in 1980 indicated that the general health of the fish was excellent, and that most of these fish were smolting during the second release (24 April). General health and physical appearance of the fish at release time was markedly improved over 1978. This may be a reflection of the decision to switch from recycled to flow-through water supplies in March. Generally low temperatures after that (Figure 1) were probably a major factor in the smolt quality. We estimate that over 70% of the fish were smolting when the test group was

Table 9.--Summary of lesion incidence (% of samples) and average intensity (scale: 1 to 3) for 9 of the 10 hatcheries sampled in 1980.[a]

Stock	Sample No.	Date	Eye muscle	Olfactory sac	Gill-lymphoid	Gill-epithelial	Gill-miscellaneous lesions
Tucannon	#3	4 April	(30%)/0.3	(35%)/0.5	(73%)/0.9	(73%)/1.4	17%
Steelhead	#5A	7 May	(80%)/0.8	(97%)/1.2	(97%)/1.3	(98%)/1.6	12%
	#7	12 June	(70%)/0.7	(98%)/1.6	(100%)/1.7	(97%)/1.6	0
Dworshak	#1	4 March	(68%)/0.7	(87%)/1.4	(85%)/1.1	(85%)/1.3	63%
Steelhead	#3	1 April	(78%)/0.9	(93%)/1.3	(98%)/1.8	(100%)/2.7	23%
	#5	29 April	(47%)/0.5	(83%)/1.0	(88%)/1.3	(95%)/1.7	13%
Big Creek	#1	8 April	(10%)/0.1	(2%)/0.0	(17%)/0.2	(62%)/0.8	2%
Fall chinook	#2	23 April	(18%)/0.2	(62%)/0.6	(37%)/0.4	(68%)/0.8	10%
	#3	6 May	(40%)/0.4	(75%)/1.0	(97%)/1.3	(100%)/1.5	2%
	#4	13 May	(38%)/0.4	(93%)/1.0	(92%)/1.2	(95%)/1.5	2%
Spring Creek	#1	10 March	(18%)/0.2	(63%)/0.7	(75%)/0.9	(80%)/1.1	8%
Fall chinook	#2	10 April	(7%)/0.1	(50%)/0.6	(27%)/0.3	(72%)/0.9	27%
	#3	8 May	(22%)/0.2	(95%)/1.1	(97%)/1.3	(100%)/1.5	2%
Leavenworth	#1	3 March	(33%)/0.3	(97%)/1.0	(100%)/1.3	(98%)/1.7	
Spring chinook	#3	31 March	(38%)/0.4	(90%)/1.1	(98%)/1.2	(98%)/1.7	
	#5	28 April	(38%)/0.4	(48%)/0.6	(72%)/1.0	(73%)/0.8	
Carson	#1	4 March	(82%)/0.8	(88%)/1.0	(85%)/1.5	(93%)/1.3	5%
Spring chinook	#2	4 April	(42%)/0.4	(90%)/1.0	(75%)/0.9	(60%)/0.7	12%
	#3	17 April	(60%)/0.6	(85%)/1.0	(72%)/0.9	(25%)/0.2	3%
	#4	12 May	(42%)/0.4	(93%)/1.0	(90%)/1.2	(53%)/0.7	3%
Kooskia	#1	5 March	(15%)/0.2	(80%)/0.8	(87%)/1.0	(87%)/1.2	15%
Spring chinook	#3	2 April	(33%)/0.3	(90%)/1.0	(67%)/0.8	(73%)/0.9	7%
	#5	30 April	(43%)/0.4	(92%)/1.0	(52%)/0.7	(68%)/0.8	20%
Rapid River	#1	6 March	(43%)/0.4	(83%)/0.8	(97%)/1.2	(100%)/1.7	4%
Spring chinook	#2	20 March	(55%)/0.6	(92%)/1.1	(92%)/1.2	(83%)/1.1	4%
	#3	3 April	(59%)/0.6	(97%)/1.1	(93%)/1.1	(82%)/1.5	8%
Willard	#1	5 March	(63%)/0.4	(98%)/1.2	(97%)/1.1	(75%)/0.9	22%
Coho salmon	#2	2 April	(47%)/0.5	(100%)/1.1	(85%)/1.0	(45%)/0.5	17%
	#3	20 May	(78%)/0.8	(97%)/1.1	(98%)/1.6	(97%)/1.2	0

[a] Brain tissue was processed and examined for all specimens except 7597 and 7598 in the Tucannon steelhead #3. Only 2 specimens showed any pathology: (Carson spring chinook #3) 8,506 had a Class II pyogranulomatous inflammation, and 8516 had a Class III retrobulbar granulomatous inflammation.

released (5th period). Gill Na^+-K^+ ATPase values could only be significantly correlated to fish size during the 4th and 5th periods prior to release. There were no significant correlations of gill Na^+-K^+ ATPase and other measured parameters.

There were no apparent deviations of plasma electrolytes from the expected values throughout the sampling season, with the exception of plasma K^+, which was frequently lower than reported in the literature.

Compilation of 1978 and 1980 data suggests that generally high mean hematocrit and hemoglobin values in northwest steelhead stocks may reflect a normal hematological condition for these anadromous strains of rainbow trout. Profiles conducted in 1980 provide excellent significant negative correlations of Hct and Hb values with water temperature, but no correlations with possible smolt indices such as gill Na^+-K^+ ATPase or plasma electrolytes. Very few of the Dworshak NFH fish had "borderline low" hematological values. MCHC levels may have reflected some changes in water quality. Although IFAT tests of kidney tissue smears from 180 specimens (total) did reveal the presence of BKD organisms, incidence of the disease was very low.

An analysis of the veterinary pathologist's data on examinations of 60 fish from each of three sampling periods indicates a general decrease in the incidence of tissue lesions throughout the season.

In general, the stock appeared to be in excellent health at the time of release of the control and test groups, and they were beginning smoltification.

Tucannon Hatchery (WDG)

General

1980 was the third year in succession that steelhead trout from the Washington Department of Game (WDG) Hatchery at Tucannon were used for the homing studies. In 1978 and 1979, we collected gill Na^{+}-K^{+} ATPase profiles, but data for the other parameters were only collected at the time of release (briefly summarized in Table 10).

Complicating factors in 1980 prevented us from collecting the standard 60 fish samples/period, and adjustments were made to suit the circumstances.

Early in the season, WDG graded steelhead for the homing studies into four size groups, one group for each circular pond. Three of the groups were sequential test releases, and the fourth served as a control. Since there were only 17,000 to 22,000 steelhead/pond, and sampling time was limited, we restricted our sample sizes in the first part of the season to 20 fish/pond in the three test ponds, and Na^{+}-K^{+} ATPase and plasma electrolyte data were derived from 2-fish rather than 3-fish pools. The control pond was sampled for Na^{+}-K^{+} ATPase only at release, as these fish were approximately the same size as the smallest release group. The releases, as reported here, are:

Release	Reporting group no.	Location	Size
Early	Group I	Pond 1	(Largest fish)
Normal	Group II	Pond 4	(Next largest fish)
Late	Group III	Pond 2	(Smallest fish)
Control (released into the Walla Walla River)	Group IV	Pond 5	(Small fish)

Table 10.--A summary of health and smoltification index data for Tucannon Hatchery steelhead at the approximate times of release in 1978 and 1979.

Condition	1978 Mean	1978 S.D.	1979 Mean	1979 S.D.
Hematological Data				
Hematocrits	48.6%	± 6.8	53.0	± 7.7
Hemoglobins	9.9	± 1.5	9.2	± 1.3
Plasma Electrolytes (mEq/l)				
Na^+	159.5	± 9.5	140.7	±11.3
Cl^-	131.6	± 6.5	127.0	± 8.7
K^+	2.4	± 2.6	2.9	± 1.7
Gill Na^+-K^+ ATP (μ moles pi/mg protein hour)				
5/08/78	18.2	± 5.0	[5/08/79] 25.9	± 9.0
5/22/78	11.7	± 4.0		
BKD - IFAT				
(% of fish with BKD bacteria present in the kidney)	21.6	---	1.7	---

Because of the diversity of sizes in the test release groups, each pond is reported as a separate entity. Histopathology and BKD (IFAT) surveys are summarized for all groups. Water temperatures were taken from one pond for each sampling period, and the seasonal profile for the four release groups is presented in Figure 6. Ambient water temperatures were below 12°C for all release groups except Group III, which was not released until 12 June.

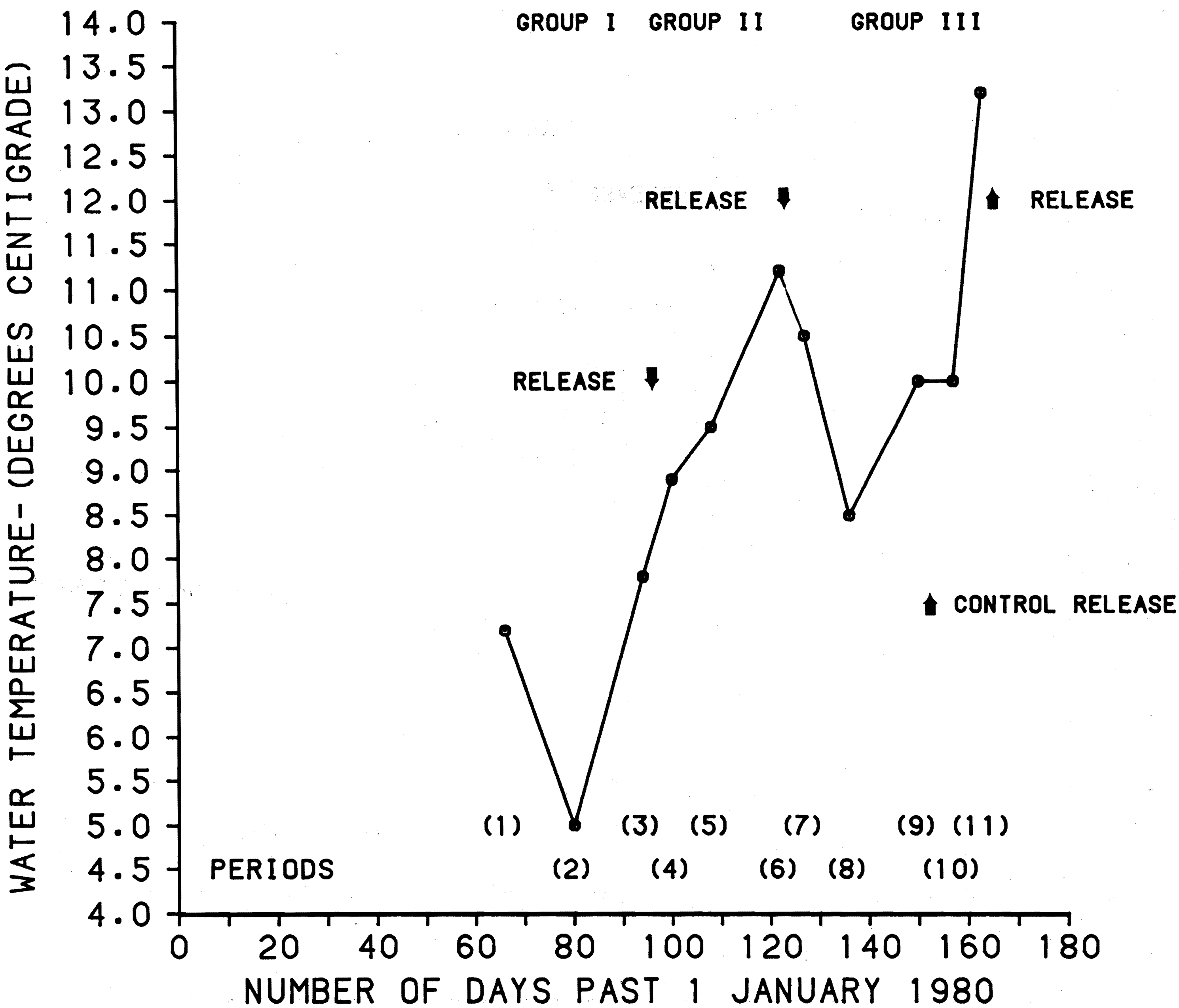
Figure 7 is a composite graph of the mean fork lengths of all four groups during the sampling period. The average size of Group IV (sampled twice) was much smaller at release than the others.

Profiles of average gill Na^+-K^+ ATPase activities for all four groups are presented in Figure 8. Note that the first two groups were released as activities were ascending, and the third (late) Group (III) was released about 40 days past a small peak. Group IV, released into the Walla Walla River, had very low gill Na^+-K^+ ATPase values. None of the Na^+-K^+ ATPase samples collected the first week in May were as high as those in 1978 or 1979 during a comparable period (Table 10). The 1980 stock was from Chelan Hatchery, whereas in 1978 and 1979 the stocks were from Skamania Hatchery.

Summaries of data collected for Tucannon steelhead throughout the 1980 season from all four ponds are presented in Tables 11, 12, 13, and 14.

Group I (Pond 1, Table 11)

Gill Na^+-K^+ ATPase.--The gill Na^+-K^+ ATPase profiles presented for homogenous populations of Tucannon steelhead in 1978 and 1979 (Skamania Hatchery stock) indicated that peak average values occurred in the first 10 days in May (Novotny and Zaugg 1979, 1981). In 1980, there was a sharp



	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
DATES	MAR	MAR	APR	APR	APR	MAY	MAY	MAY	MAY	JUNE	JUNE
(1980)	7	21	4	10	18	2	7	16	30	6	12

Figure 6.--Water temperatures measured at Tucannon Hatchery during the 1980 sampling period.

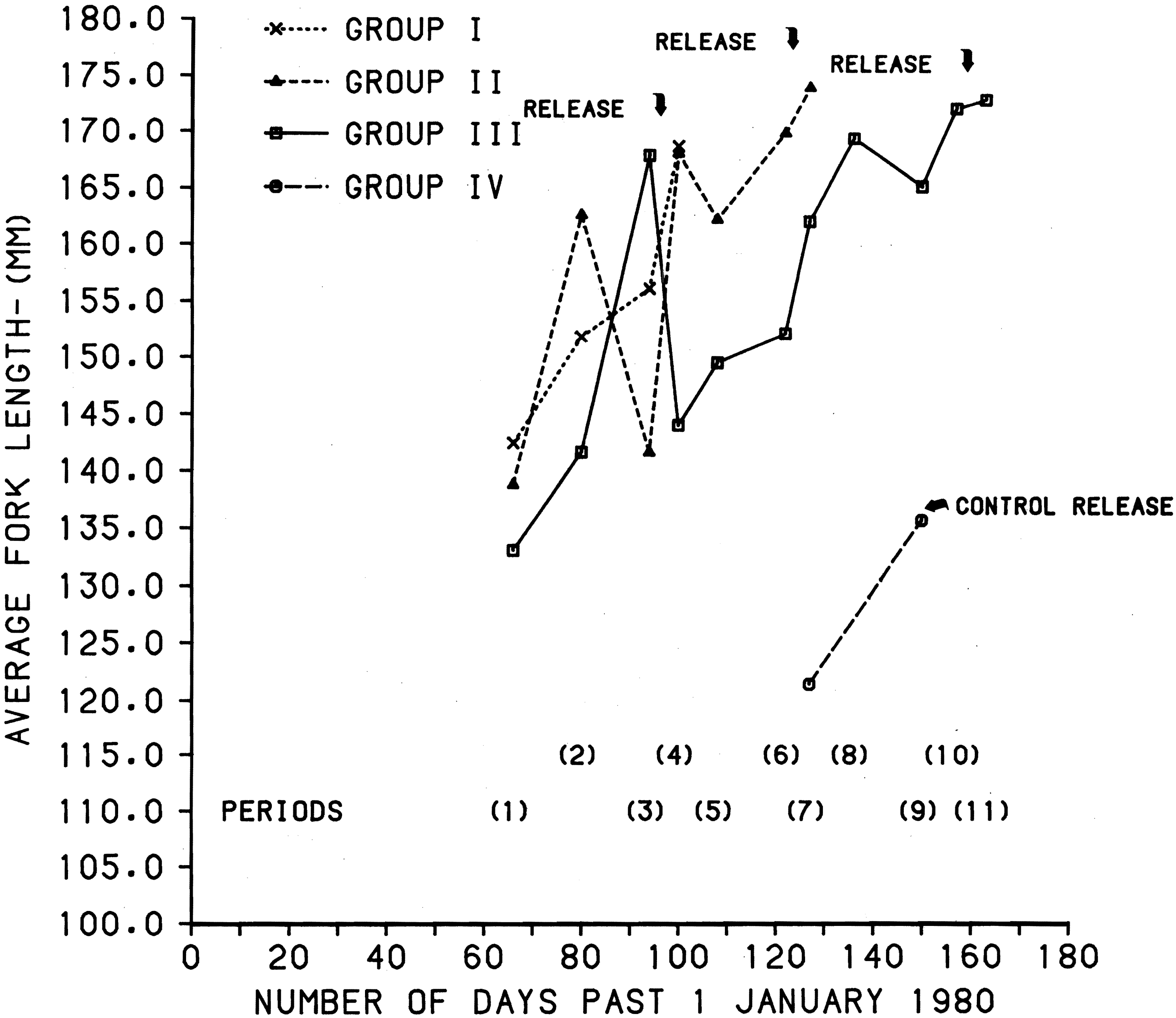


Figure 7.--Average fork lengths of steelhead sampled from the four Tucannon Hatchery ponds during spring 1980.

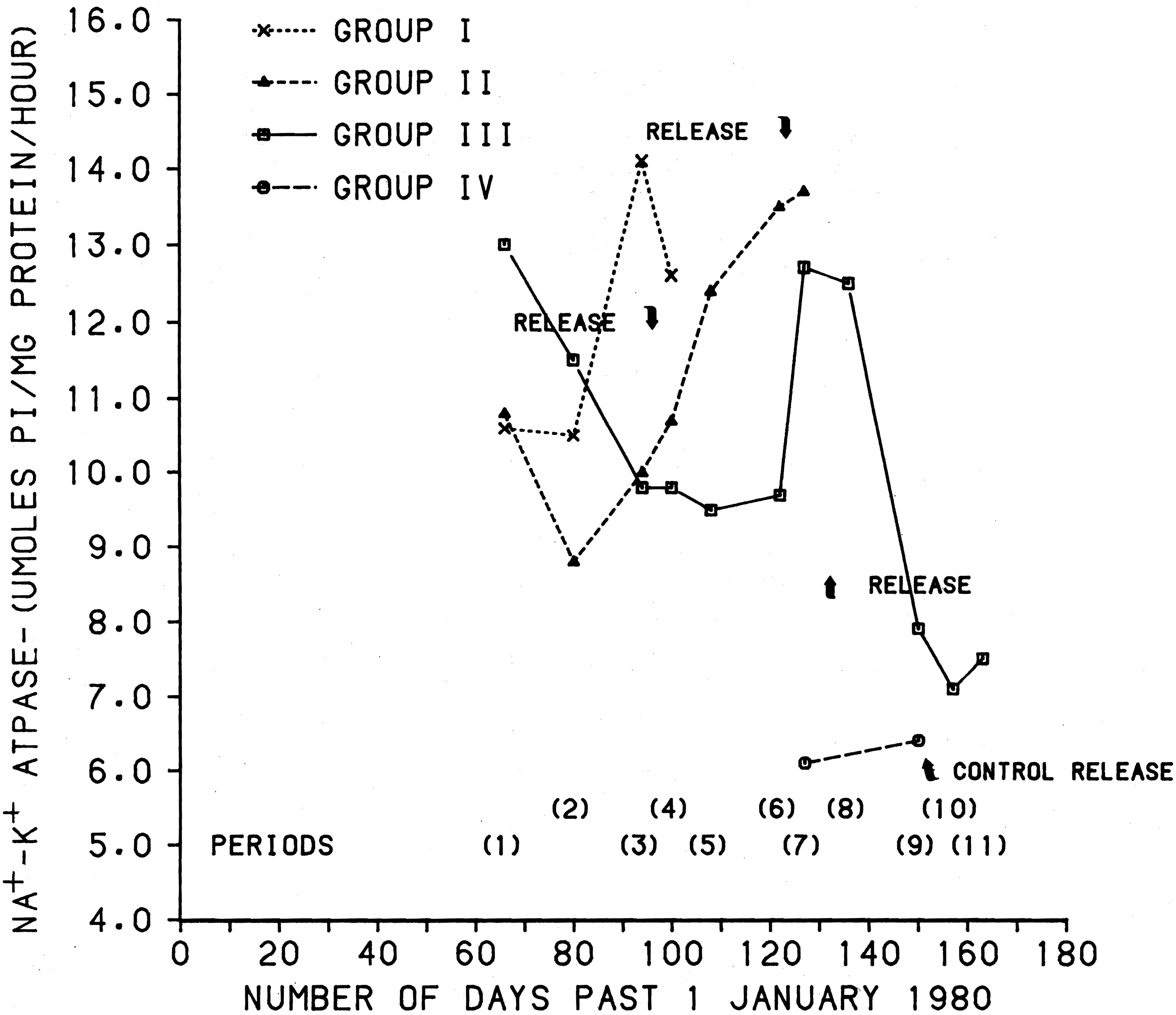


Figure 8.--Average gill Na^+-K^+ ATPase values for four release groups of Tucannon Hatchery steelhead during spring 1980.

Table 11.--Summary data for the spring (1980) sampling of Tucannon Hatchery steelhead; with means, standard deviations ( ), and ranges. Group I, Pond 1, first release, n = 20.

Item	Period 1	2	3	4
Date	7 March	21 March	4 April	10 April
Days>Ja1[a]	66	80	94	100
Temp. °C[b]	7.2	5.0	7.8	8.9
Avg. Fk Ln[c]	142.4	151.8	156.1	168.6
	(10.7)	(13.4)	(11.0)	(8.7)
(Range)	124-162	118-176	125-172	153-192
Avg. ATP Fk Ln[d]	142.4	151.8	156.1	168.6
	(10.7)	(13.4)	(11.0)	(8.7)
(Range)	124-162	118-176	125-172	153-192
Avg. ATP[e]	10.6	10.5	14.1	12.6
	(1.3)	(1.2)	(1.9)	(2.2)
(Range)	8.0-12.6	8.5-13.2	10.8-17.5	9.2-16.0
Avg. Hct[f]	45.0	49.4	46.9	51.3
	(4.6)	(6.2)	(3.7)	(4.2)
(Range)	35-55	40-62	42-56	45-60
Avg. Hb[g]	8.9	8.3	10.0	---
	(0.9)	(1.3)	(0.7)	---
(Range)	8.0-10.7	5.7-10.7	8.4-11.3	---
Avg. MCHC[h]	19.5	16.8	21.4	---
	(1.8)	(1.6)	(2.3)	---
(Range)	16.9-23.8	13.6-19.4	16.8-26.2	---
Avg. Na^+[i]	137.3	144.0	160.7	---
	(5.3)	(8.3)	(3.5)	---
(Range)	131-146	129-155	154-167	---
Avg. K^+[j]	0.41	0.46	1.05	---
	(0.08)	(0.25)	(0.12)	---
(Range)	0.36-0.50	0.23-0.73	0.80-1.17	---
Avg. Cl^-[k]	117.6	139.4	130.4	---
	(12.0)	(6.2)	(8.8)	---
(Range)	92-130	127-148	113-144	---
Na^+/Cl^-[l]	1.11	1.03	1.24	---
	(0.03)	(0.06)	(0.07)	---
(Range)	1.06-1.15	0.96-1.18	1.36-1.36	---

a/ Days>Ja1: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

Table 12.--Summary data for the spring (1980) sampling of Tucannon Hatchery steelhead, with means, standard deviations ( ). and ranges. Group II, second release. n = 20.

Item	Period 1	2	3	4	5	6	7
Date	7 March	21 March	4 April	10 April	18 April	2 May	7 May
Days>Jal a/	66	80	94	100	108	122	127
Temp. °C b/	7.2	5.0	7.8	8.9	9.5	11.2	10.5
Avg. Fk Ln c/	138.8	162.6	141.6	168.0	162.2	169.8	173.9
	(17.1)	(5.7)	(8.8)	(14.6)	(15.0)	(17.9)	(12.7)
(Range)	107-162	154-173	122-160	134-195	120-185	117-192	139-196
Avg. ATP Fk Ln d/	138.8	162.6	141.6	168.0	162.2	169.8	173.9
	(17.1)	(5.7)	(8.8)	(14.6)	(15.0)	(17.9)	(12.7)
(Range)	107-162	154-173	122-160	134-195	120-185	117-192	139-196
Avg. ATP e/	10.8	8.8	10.0	10.7	12.4	13.5	13.7
	(2.4)	(1.8)	(1.7)	(2.2)	(1.8)	(3.9)	(3.5)
(Range)	8.1-16.5	6.1-11.5	6.3-12.1	9.8-12.5	9.7-15.7	7.6-18.8	9.0-21.0
Avg. Hct f/	49.5	43.6	46.2	46.5	45.7	54.0	48.6
	(5.6)	(6.1)	(5.1)	(2.9)	(5.6)	(5.9)	(5.1)
(Range)	40-63	33-57	39-57	41-53	37-60	40-68	39-59
Avg. Hb g/	9.5	7.4	9.4	---	7.7	8.8	---
	(0.90)	(0.92)	(1.00)	---	(0.85)	(0.97)	---
(Range)	7.7-11.7	6.3-10.0	7.7-11.6	---	6.3-9.0	7.1-10.6	---
Avg. MCHC h/	19.2	17.1	20.0	---	16.9	16.4	---
	(1.5)	(1.2)	(3.2)	---	(1.1)	(1.6)	---
(Range)	15.9-21.6	14.8-19.1	14.5-29.2	---	14.5-20.7	14.0-19.3	---
Avg. Na^+ i/	135.0	146.1	152.3	---	142.3	140.1	---
	(8.0)	(6.0)	(9.1)	---	(11.7)	(14.4)	---
(Range)	123-143	137-154	140-164	---	109-160	88-158	---
Avg. K^+ j/	0.8	0.45	1.11	---	0.64	0.59	---
	(0.29)	(0.15)	(0.50)	---	(0.26)	(0.31)	---
(Range)	0.56-1.50	0.24-0.79	0.63-2.00	---	0.34-1.16	0.29-1.50	---
Avg. Cl^- k/	110.5	135.4	122.0	---	139.2	137.4	---
	(12.9)	(6.3)	(7.3)	---	(8.8)	(12.3)	---
(Range)	89-126	121-141	104-131	---	118-155	86-157	---
Na^+/Cl^- l/	1.23	1.08	1.25	---	1.03	1.02	---
	(0.14)	(0.04)	(0.09)	---	(0.07)	(0.08)	---
(Range)	1.08-1.54	1.04-1.16	1.10-1.40	---	0.92-1.16	0.89-1.17	---

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

Table 13.--Summary data for the spring (1980) sampling of Tucannon steelhead, with means, standard deviations ( ), and ranges. Group III; Pond 2; third release; n = 20 (periods 1 - 4), n = 30 (periods 5-10); and n = 60 (period 1).

Item	Period 1	2	3	4	5	6	7	8	9	10	11
Date	7 March	21 March	4 April	10 April	18 April	2 May	7 May	6 May	30 May	6 June	12 June
Days>Jal[a]	66	80	94	100	108	122	127	136	150	157	163
Temp. °C[b]	7.2	5.0	7.8	8.9	9.5	11.2	10.5	8.5	10.0	10.0	13.2
Avg. Fk Ln[c]	133.0	141.6	167.8	144.0	149.5	152.1	162.0	169.3	165.1	172.0	172.8
	(12.8)	(10.7)	(10.4)	(15.4)	(9.1)	(17.0)	(15.9)	(9.9)	(17.9)	(12.2)	(16.7)
(Range)	110-156	125-167	145-184	111-169	134-172	112-179	108-182	143-189	127-195	146-199	126-208
Avg. ATP Fk Ln[d]	133.0	141.6	167.8	144.0	149.5	152.1	162.0	169.3	165.1	172.0	173.4
	(12.8)	(10.7)	(10.4)	(15.4)	(9.1)	(17.0)	(15.9)	(9.9)	(17.9)	(12.2)	(19.1)
(Range)	110-156	125-167	145-184	111-169	134-172	112-179	108-182	143-189	127-195	146-199	126-208
Avg. ATP[e]	13.0	11.5	9.8	9.8	9.5	9.7	12.7	12.5	7.9	7.1	7.5
	(1.5)	(1.8)	(1.7)	(1.2)	(1.5)	(2.7)	(2.9)	(4.4)	(1.7)	(0.5)	(2.1)
(Range)	10.2-14.8	8.3-15.3	7.1-12.9	7.9-11.5	7.1-11.9	6.7-13.6	7.9-16.1	8.0-23.3	5.8-10.5	6.3-7.7	3.6-14.9
Avg. Hct[f]	47.7	46.6	46.3	46.9	46.9	53.2	54.4	54.7	---	51.8	54.7
	(6.6)	(4.8)	(4.1)	(4.5)	(6.7)	(7.0)	(5.5)	(7.2)	---	(6.3)	(5.9)
(Range)	35-62	40-56	41-57	40-55	27-59	36-66	43-64	41-70	---	41-69	41-75
Avg. Hb[g]	9.2	7.9	9.6	---	7.7	8.9	---	9.4	---	9.6	9.7
	(1.2)	(0.7)	(0.9)	---	(1.2)	(1.2)	---	(1.6)	---	(1.1)	(1.4)
(Range)	7.0-11.7	6.3-9.0	8.1-12.3	---	4.0-9.7	6.5-11.6	---	6.7-12.3	---	80-12.7	7.0-16.9
Avg. MCHC[h]	19.4	17.0	20.8	---	16.5	16.7	---	17.8	---	18.4	17.8
	(1.6)	(1.8)	(2.4)	---	(1.3)	(1.5)	---	(3.7)	---	(1.4)	(1.5)
(Range)	17.5-22.4	14.3-20.8	17.6-28.0	---	14.5-19.4	14.1-19.6	---	13.3-26.8	---	150-165	14.3-22.9
Avg. Na^+[i]	137.4	147.3	158.9	---	148.3	141.9	---	148.0	---	160.0	148.2
	(11.3)	(8.0)	(5.0)	---	(6.5)	(11.5)	---	(3.6)	---	(2.9)	(16.4)
(Range)	117-154	140-165	150-165	---	138-163	117-158	---	145-152	---	150-165	130-164
Avg. K^+[j]	0.59	0.56	1.79	---	0.76	0.52	---	---	---	0.72	0.97
	(0.29)	(0.11)	(0.83)	---	(0.51)	(0.15)	---	---	---	(0.38)	(0.65)
(Range)	0.31-1.10	0.41-0.68	1.07-3.95	---	0.36-2.15	0.39-0.72	---	---	---	0.34-1.59	0.35-2.62
Avg. Cl^-[k]	124.0	139.4	128.5	---	131.3	144.6	---	127.8	---	128.6	125.2
	(9.2)	(8.1)	(4.9)	---	(6.0)	(9.0)	---	(6.7)	---	(6.2)	(16.4)
(Range)	113-140	126-155	120-134	---	119-141	124-159	---	108-137	---	114-138	92-169
Na^+Cl^-[l]	1.10	1.05	1.24	---	1.13	6.97	---	1.13	---	1.26	1.21
	(0.09)	(0.05)	(0.05)	---	(0.7)	(0.07)	---	(0.01)	---	(0.07)	(0.13)
(Range)	0.97-1.22	0.98-1.14	1.16-1.34	---	1.01-1.25	0.80-1.15	---	1.12-1.13	---	1.11-1.41	0.93-1.4

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

Table 14.--Summary data for the spring (1980) sampling of Tucannon Hatchery steelhead, with means, standard deviations ( ), and ranges. Group IV, Pond 5, Control (Walla Walla River), n = 30.

Item	Period 7	Period 9
Date	7 May	30 May
Days>Jal[a]	127	150
Temp. °C[b]	10.5	10.0
Avg. Fk Ln[c]	121.4	135.7
	(11.9)	(14.7)
(Range)	97-146	113-164
Avg. ATP Fk Ln[d]	121.4	135.7
	(11.9)	(14.7)
(Range)	79-146	113-164
Avg. ATP[e]	6.1	6.4
	(0.9)	(3.1)
(Range)	5.0-8.2	1.0-12.4
Avg. Hct[f]	---	53.9
	---	(6.2)
(Range)	---	39-66
Avg. Hb[g]	---	8.7
	---	(1.1)
(Range)	---	6.0-11.7
Avg. MCHC[h]	---	16.3
	---	(1.6)
(Range)	---	12.8-20.5
Avg. Na^+[i]	---	147.0
	---	(4.6)
(Range)	---	141-151
Avg. K^+[j]	---	---
	---	---
(Range)	---	---
Avg. Cl^-[k]	---	136.0
	---	(8.9)
(Range)	---	113-155
Na^+/Cl^-[l]	---	1.12
	---	(0.14)
(Range)	---	1.03-1.34

[a] Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
[b] Temp.-°C: Water temperature (in degrees C.) measured for that period.
[c] Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
[d] Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
[e] Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
[f] Avg. Hct: The average hematocrits for that period (% packed cells).
[g] Avg. Hb: The average hemoglobins for that period (in g/dl).
[h] Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
[i] Avg. Na^+: The average plasma sodium for that period (in meq/l).
[j] Avg. K^+: The average plasma potassium for that period (in meq/l).
[k] Avg. Cl^-: The average plasma chloride for that period (in meq/l).
[l] Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

increase in the average gill Na^+-K^+ ATPase activity early in the season (Figure 8). The drop in activity (at release) from the previous sampling period probably does not represent a true decline since there is no statistical difference in the two values, and peak Na^+-K^+ ATPase activities for steelhead normally occur in May.

There were no significant correlations in this Group (I) between average gill Na^+-K^+ ATPase values and average fork lengths, plasma electrolytes, hematocrits, hemoglobins, or water temperatures during the sampling periods, nor were there any correlations between Na^+-K^+ ATPase values and other parameters measured during any one sampling period.

Plasma electrolytes.--Average plasma Na^+ and Cl^- in Group I reached peak levels equal to or exceeding those measured in May of 1978 and 1979 (Tables 10 and 11). Average plasma Na^+ and Cl^- values diverged sharply as gill Na^+-K^+ ATPase activities began to rise (Table 11).

Average plasma K^+ values of fish in Group I (Table 11) never reached the 1978 and 1979 levels (Table 10), and were below the minimum expected and reported values of other researchers. Although rising rapidly at the time of release, plasma K^+ levels for Groups II and III barely peaked at the minimum expected level of 1.5 mEq/l (Tables 12 and 13). All mean plasma K^+ values followed a trend (similar to that of the Dworshak NFH steelhead) of peaking in April, followed by a general decline.

Hematology.--There were no indications of hematological deficiencies in any of the Group I fish examined (Table 11). There were fluctuations in average hematocrit and hemoglobin levels, with sharp increases prior to release (Table 11).

Comments.--A sample of fish taken from Pond 1 on 8 April ($\bar{X}$ FkLn = 158.8 mm; n = 33), just before transfer of the entire lot to hauling trucks for transportation and release, indicated a significant size differential (P = 0.007) from the subsample collected on 10 April ($\bar{X}$ FkLn = 168.6 mm; n = 20).

Group II (Pond 4, Table 12)

Gill Na^+-K^+ ATPase.--Group II steelhead were released 7 May, approximately the same time as 1978 and 1979 test fish. The Na^+-K^+ ATPase profile paralleled that of Group I, (Figure 8), but perhaps due to the different stock of fish, the level of peak activity was considerably lower than the activities measured at the same time in 1978 and 1979 (Table 10). The apparent growth of this stock was good, and average size of the samples was larger than any other group at release (Figure 7). Although no fish were held over from this pond for further monitoring of Na^+-K^+ ATPase, it would appear that the release was made near the peak of activity (Figure 8).

There was a significant positive correlation between average gill Na^+-K^+ ATPase values and water temperature during the periodic sampling of Group II (Figure 9). Average gill Na^+-K^+ ATPase could not be significantly correlated with averages of other parameters measured.

Correlations between gill Na^+-K^+ ATPase values of Group II fish and average fork lengths for each Na^+-K^+ ATPase value generally increased as spring progressed, but were not highly significant until the sixth period, 5 days prior to release (Table 15).

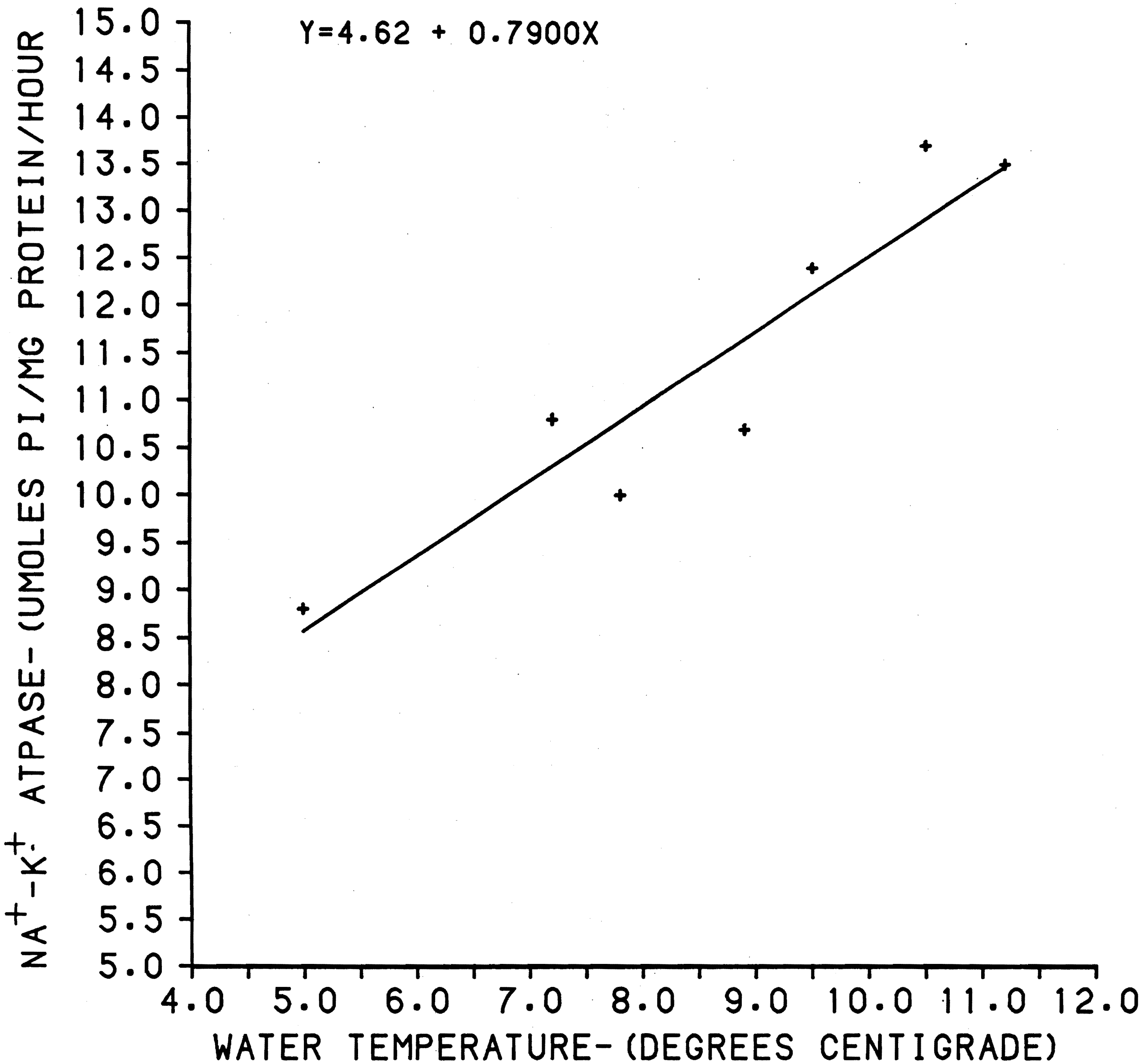


Figure 9.--Regression of average gill Na^+-K^+ ATPase values of steelhead in Pond 4 (second release group) on water temperature at Tucannon Hatchery during spring 1980. r = 0.938; P = 0.002.

Table 15.--Correlation coefficients between Gill Na^{+}-K^{+} ATPase values for each sampling period, and average fork length of Tucannon Hatchery steelhead used to provide gill samples in 1980 from Group II (Pond 4).

Item	Period 1	2	3	4	5	6	7
Correlation coefficient (DF=8)	0.44	-0.09	-0.19	0.13	0.69[a]	0.80[b]	0.45

a/ $P<0.02$

b/ $P<0.01$

If smolting was well developed between the sixth and seventh periods, and we use the sixth period as an approximate index, gill Na^{+}-K^{+} ATPase values of 15 u moles Pi/mg protein/hour or more would represent 50% of the samples collected, and would probably be a high index of smoltification. The regression curve in Figure 10 suggests that we could expect fish >175 mm to have Na^{+}-K^{+} ATPase values >15.

On the basis of this information, approximately 50% of the Group II steelhead would have been smolting between the sixth period and release (Figure 11).

Plasma electrolytes.--Data for Group II (Table 12) suggest that average plasma Na^{+} and Cl^{-} values were well within the suggested ranges, but that some individual values were below the expected low in some periods. Mean plasma K^{+} levels were (as in the Dworshak NFH steelhead) erratic, lower than the expected low range, and lower than in 1978 or 1979 (Table 10). Mean plasma Na^{+} reached an apparent peak early in April and mean plasma Cl^{-} reached a minimum decline at the same time (Table 12).

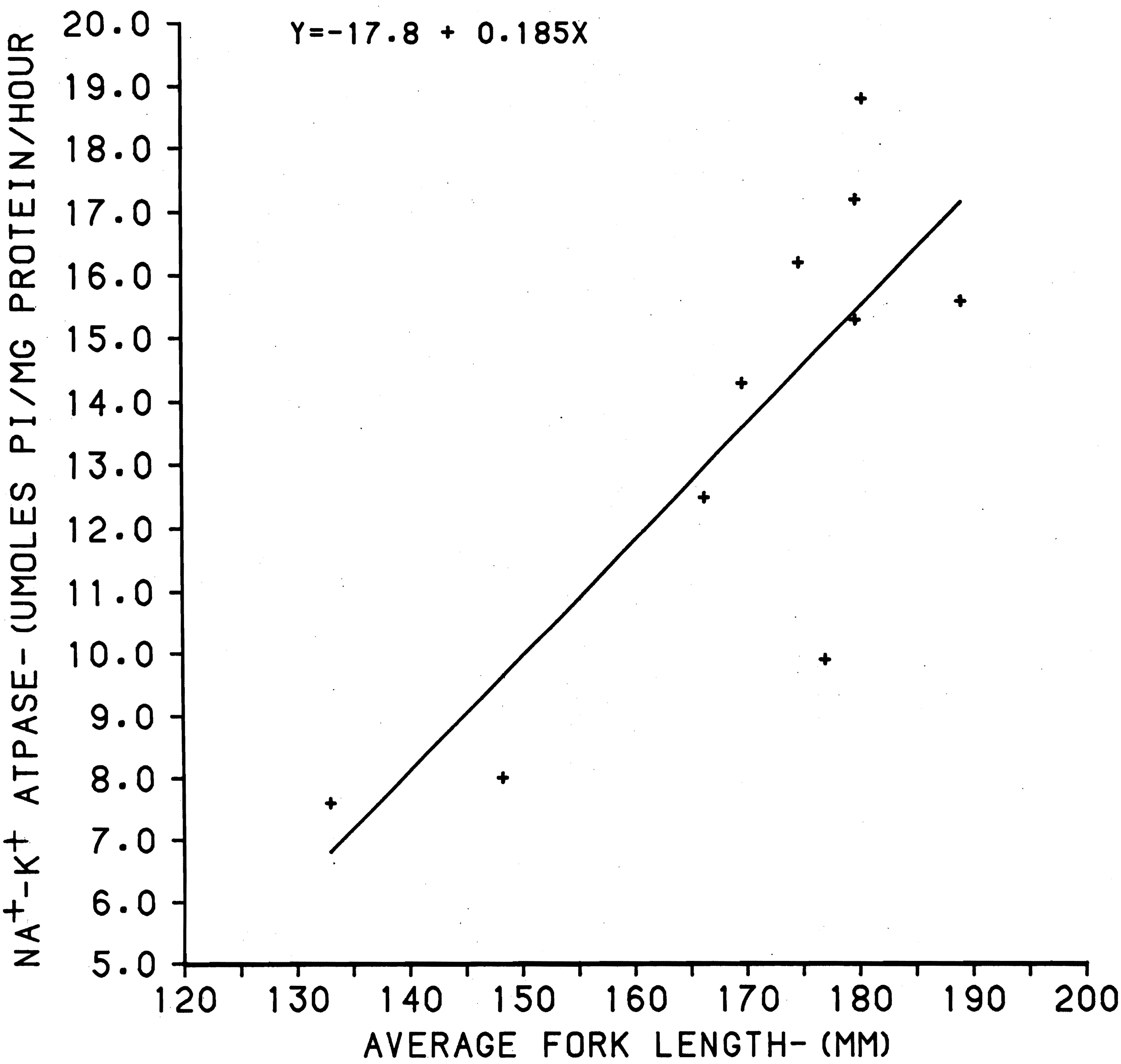


Figure 10.--Regression of average gill Na^{+}-K^{+} ATPase activity on average fork length of steelhead (Group II) in the sixth sampling period (3 fish pools for each Na^{+}-K^{+} ATPase analysis), 2 May 1980 (Tucannon Hatchery). $r = 0.800$; $P < 0.05$.

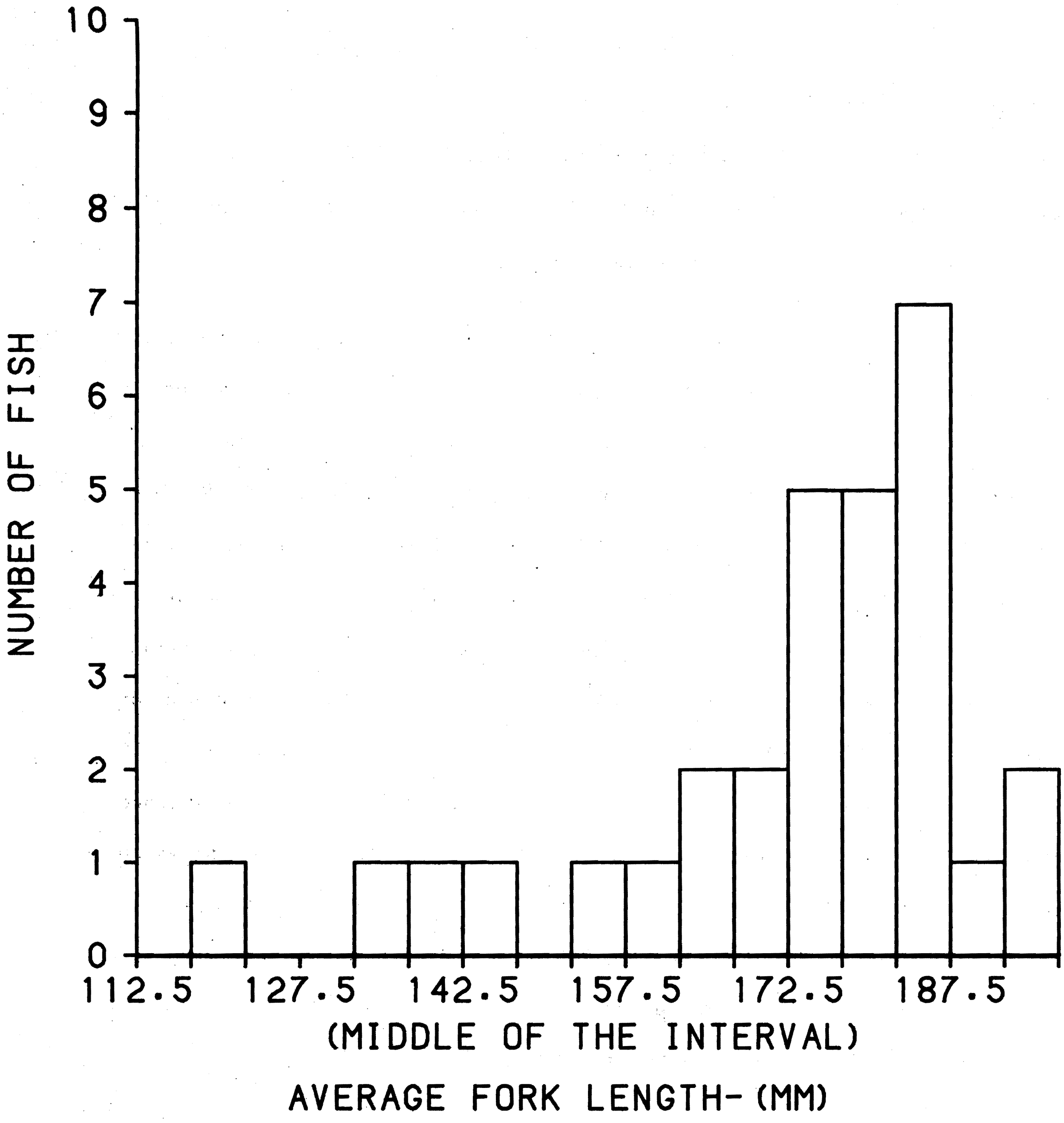


Figure 11.--Histogram of length-frequencies of Group II Tucannon Hatchery steelhead sampled in the sixth period.

These high and low peaks also occurred at the same time for Group I (Table 11).

Plasma electrolytes of Group II could not be correlated with water temperature or Na^+-K^+ ATPase activity, but mean plasma chlorides were significantly correlated with mean fork lengths (Figure 12), and mean plasma K^+ values were significantly correlated with MCHC (Figure 13). Both plasma K^+ and MCHC can be stress indicators.

Hematology.--There were no indications of average hematological deficiencies in the Group II steelhead. Some of the individual hematocrits and hemoglobins were much higher than any expected values (Table 12), although not much different from samples collected in 1978 and 1979 (Table 10). Both hematocrits and hemoglobins rose and fell at the same times throughout the season, with hematocrits reaching a peak just prior to release (Table 12). There were no significant correlations between average hematological data and other factors measured, with the exception of average fork length, which was inversely related to MCHC (Figure 14). There was no significant correlation between average hematocrit and average hemoglobin values. However, in four of five sample periods in which hemoglobin was measured, individual hematocrit and hemoglobin values were significantly correlated. MCHC averages of steelhead in Pond 4 (Group II) paralleled those of the first release (Group I) and then followed a trend similar to that of the Dworshak NFH steelhead (Tables 3, 11, and 12).

Comments.--A sample of 149 fish from Pond 4 was taken for length and weight measurement during transfer to transportation vehicles on the day of release. The average fork length was 170.2 mm ($\pm$17.2), which was not

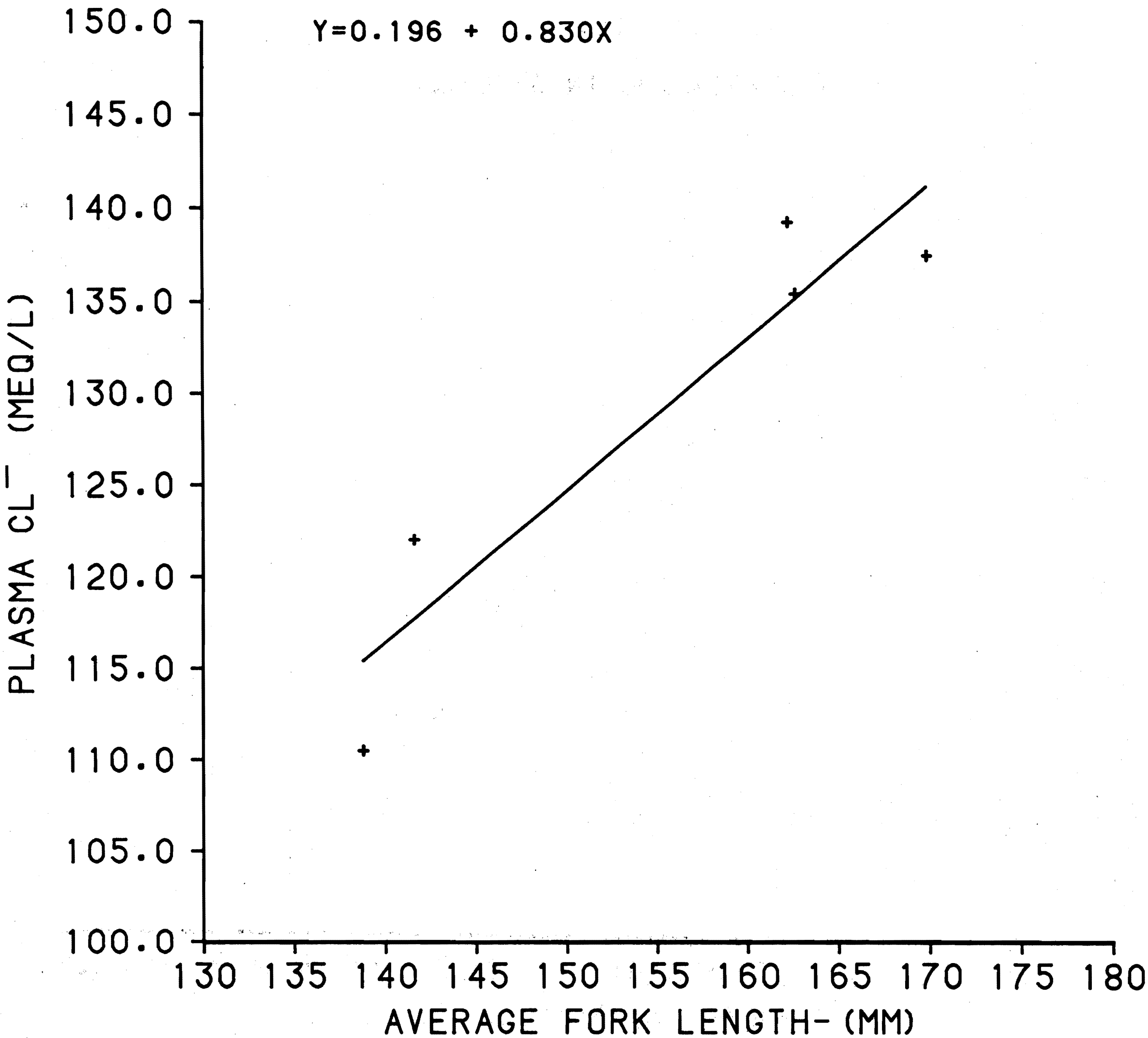


Figure 12.--Regression of average plasma Cl^- values of steelhead in Pond 4 (Group II) on average fork lengths at Tucannon Hatchery, spring 1980. $r = 0.936$; $P < 0.02$.

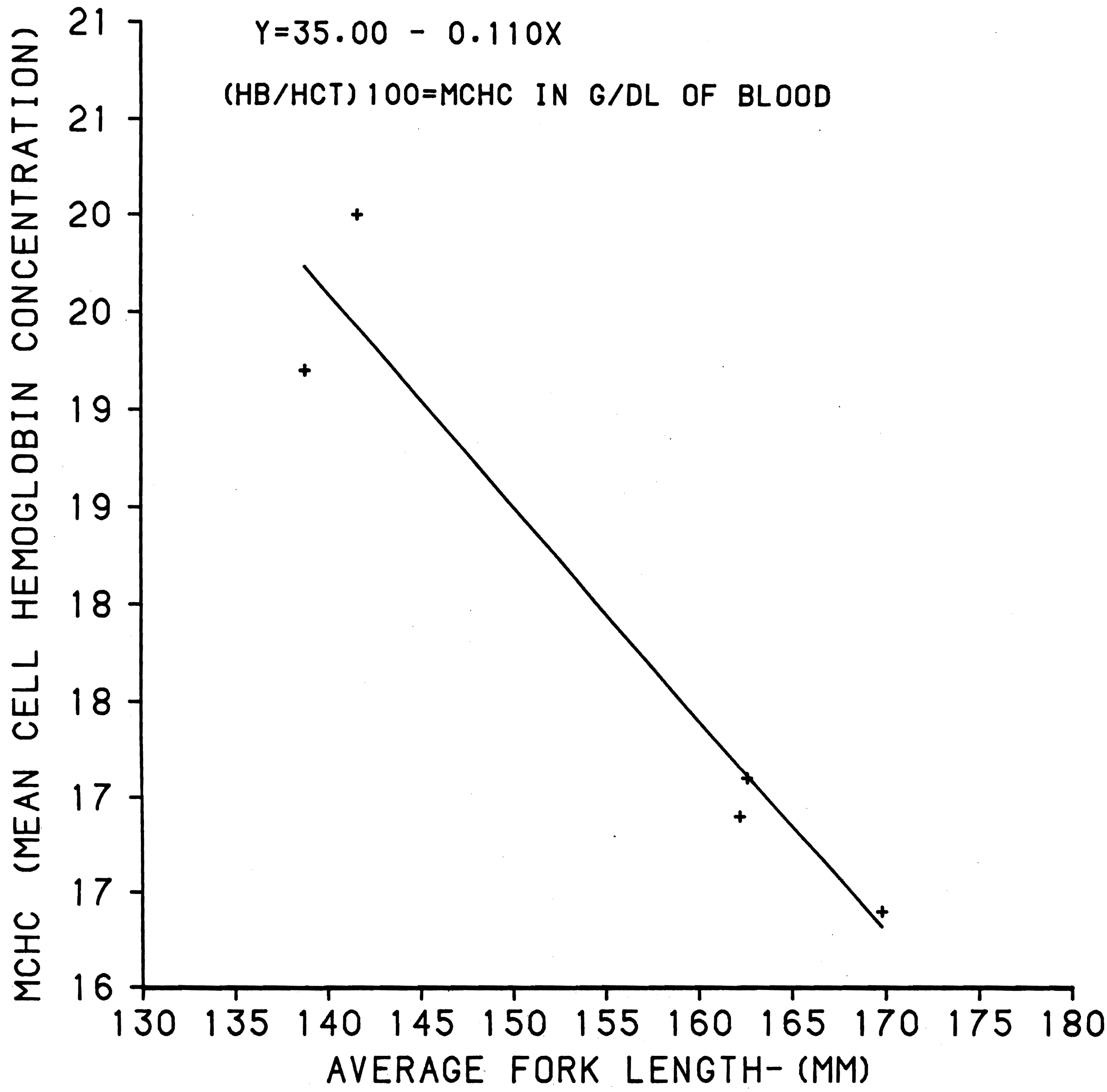


Figure 14.--Regression of average mean cell hemoglobin concentrations (MCHC) on average fork lengths of Tucannon Hatchery steelhead in Pond 4 (Group II) during spring 1980. $r = -0.965$; $P < 0.01$.

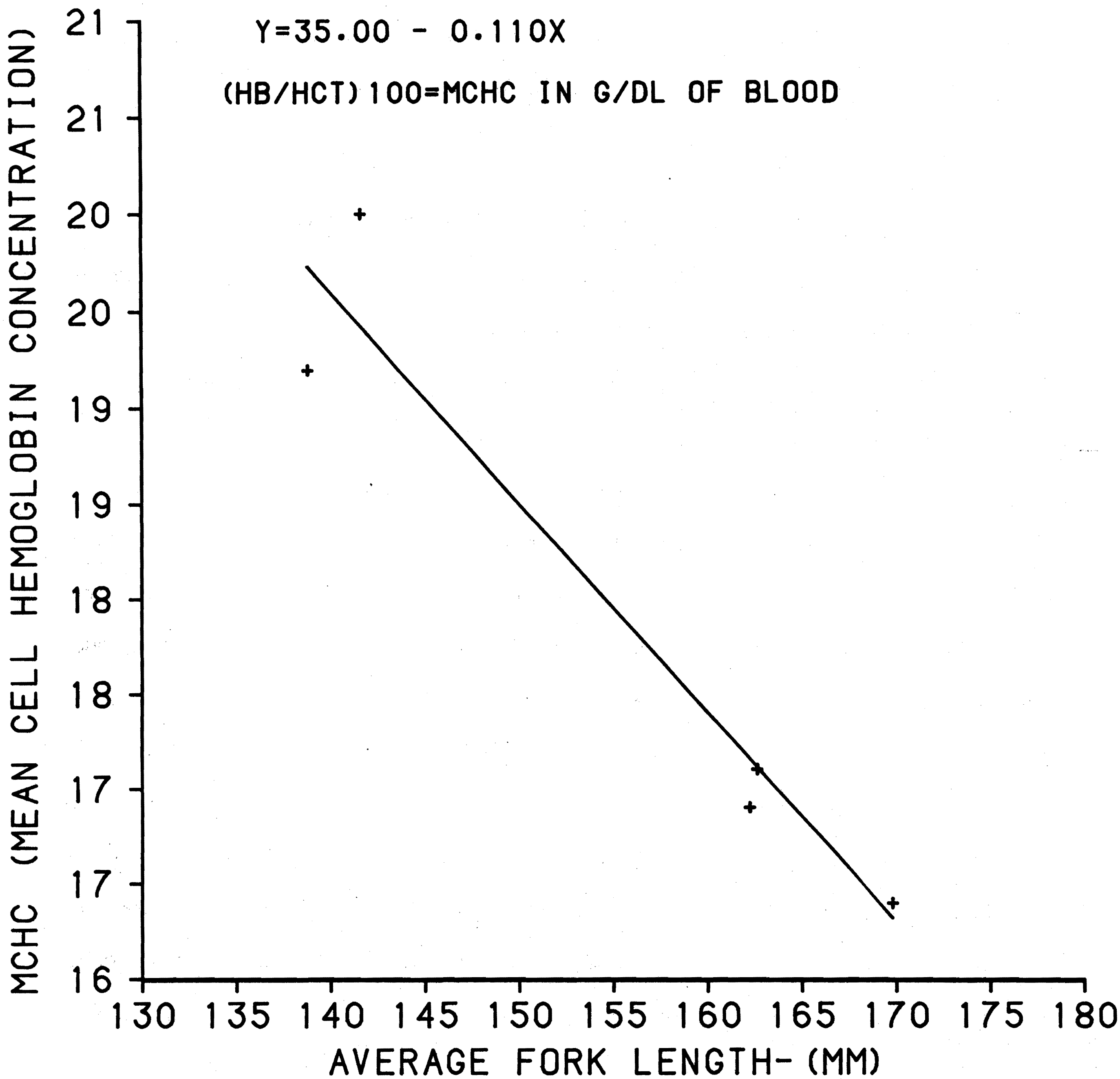


Figure 14.--Regression of average mean cell hemoglobin concentrations (MCHC) on average fork lengths of Tucannon Hatchery steelhead in Pond 4 (Group II) during spring 1980. $r = -0.965$; $P < 0.01$.

significantly different from mean fork lengths of samples collected for the health index (Table 12). The average weight was 54.9 g.

Group III (Pond 2, Table 13)

Gill Na^+-K^+ ATPase.--The Group III steelhead were released on 12 June. The Na^+-K^+ ATPase profile was parallel to and similar to that of Groups I and II early in the season, and shifted forward in time (Figure 8). However, the peak of the average Na^+-K^+ ATPase values occurred at the same time and with almost the same intensity as the Group II steelhead on 8 May. This lasted for only 1 week and was followed by a steep decline. When the Group III steelhead were released, the average Na^+-K^+ ATPase value was at its lowest level. It is interesting to note that the maximum deviations in Na^+-K^+ ATPase activity in each group occurred at the peaks (Figure 8). Average fork lengths of Group III fish sampled during the last week of peak Na^+-K^+ ATPase activity (16 May) were not different from average fork lengths of Group I (10 April) or Group II fish (7 May) at release, and the average size of Group III at release (12 June) was almost identical to Group II (7 May) at release (Figure 7). The additional month of rearing time for Group III did not improve growth, and may have resulted in a post-smolt condition and reluctance to migrate.

If gill Na^+-K^+ ATPase activity can be considered one of the criteria for smolt indexing, then Group III fish were probably smolting during the week that the Group II fish were released. Note that elevated Na^+-K^+ ATPase activity in both Groups II and III had a high frequency of occurrence on 7 May, and Group III had a low frequency of occurrence by 12 June (Figure 15).

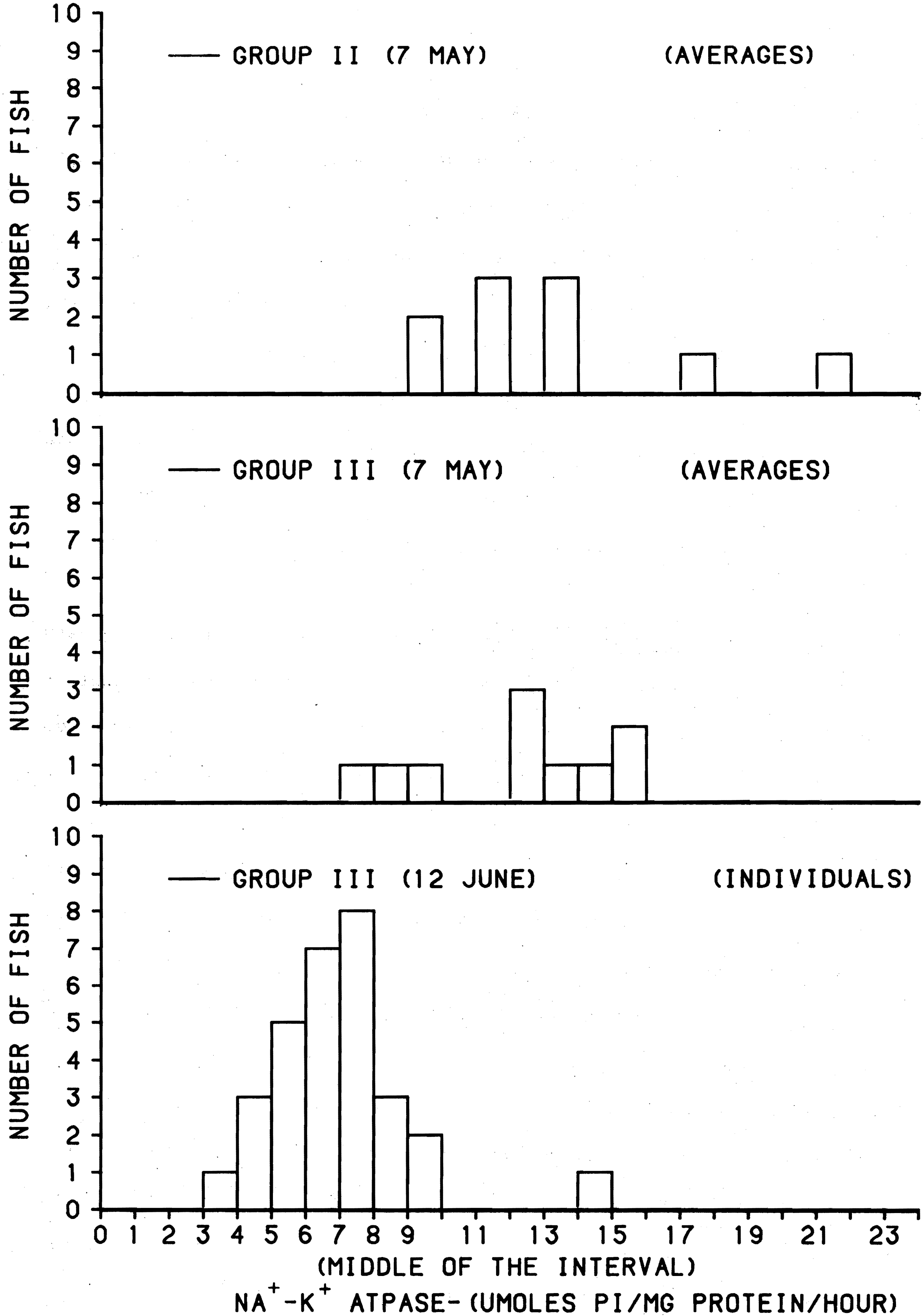


Figure 15.--Frequency histograms of average gill Na^+-K^+ ATPase values from Group II and Group III Tucannon Hatchery steelhead collected 7 May 1980, and individual Na^+-K^+ ATPase values from Group III fish collected 12 June.

We could find no significant correlations between average gill Na^{+}-K^{+} ATPase values and averages of other factors measured throughout the sampling periods (including water temperature). However, like Group II steelhead, there was a progressive increase throughout the spring in correlations between average Na^{+}-K^{+} ATPase values and corresponding fork lengths for any one period (Table 16). Furthermore, these correlation coefficients reached the most significant levels on 2 May for both Groups II and III, and from that point on declined rapidly. This would indicate that on 12 June, a depressed Na^{+}-K^{+} ATPase average for the population was not caused by the influence of larger post-smolted fish, and that all size groups had entered a post-smolt condition.

Plasma electrolytes.--Data (Table 13) for Group III (Pond 2) suggests that average plasma Na^{+} and Cl^{-} were also (as with Group II) within expected values, but that some individual samples fell below the expected levels in certain periods. Non-hemolyzed average plasma K^{+} values were (again) lower than expected. Mean plasma Na^{+} and Cl^{-} reached their first maximum divergence on 4 April (Table 13), which was also the time of maximum divergence for the first two groups. There was a maximum convergence 1 month later (2 weeks later than Group II), followed by another (greater) maximum divergence in early June. The mean plasma K^{+} and Na^{+}/Cl^{-} ratios followed the same cyclical pattern as Group II.

Mean plasma electrolyte values for the Group III steelhead could not be correlated with water temperature or mean Na^{+}-K^{+} ATPase values. There was a positive correlation between average plasma Na^{+} values and average fork lengths for Group III (Figure 16); whereas in Group II, it was the average Cl^{-} that was correlated to size. This suggests a time or

Table 16.--Correlation coefficients between Gill Na^{+}-K^{+} ATPase values for each sampling period, and average fork lengths of Tucannon Hatchery steelhead used to provide gill samples in 1980 from Group III (Pond 2).

	Period										
Item	1	2	3	4	5	6	7	8	9	10	11
Correlation coefficient (DF=8)	0.26	0.45	0.43	0.03	0.45	0.87[a]	0.79[b]	0.32	0.64[c]	0.37	0.30

a/ P<0.001

b/ P<0.01

c/ P<0.05

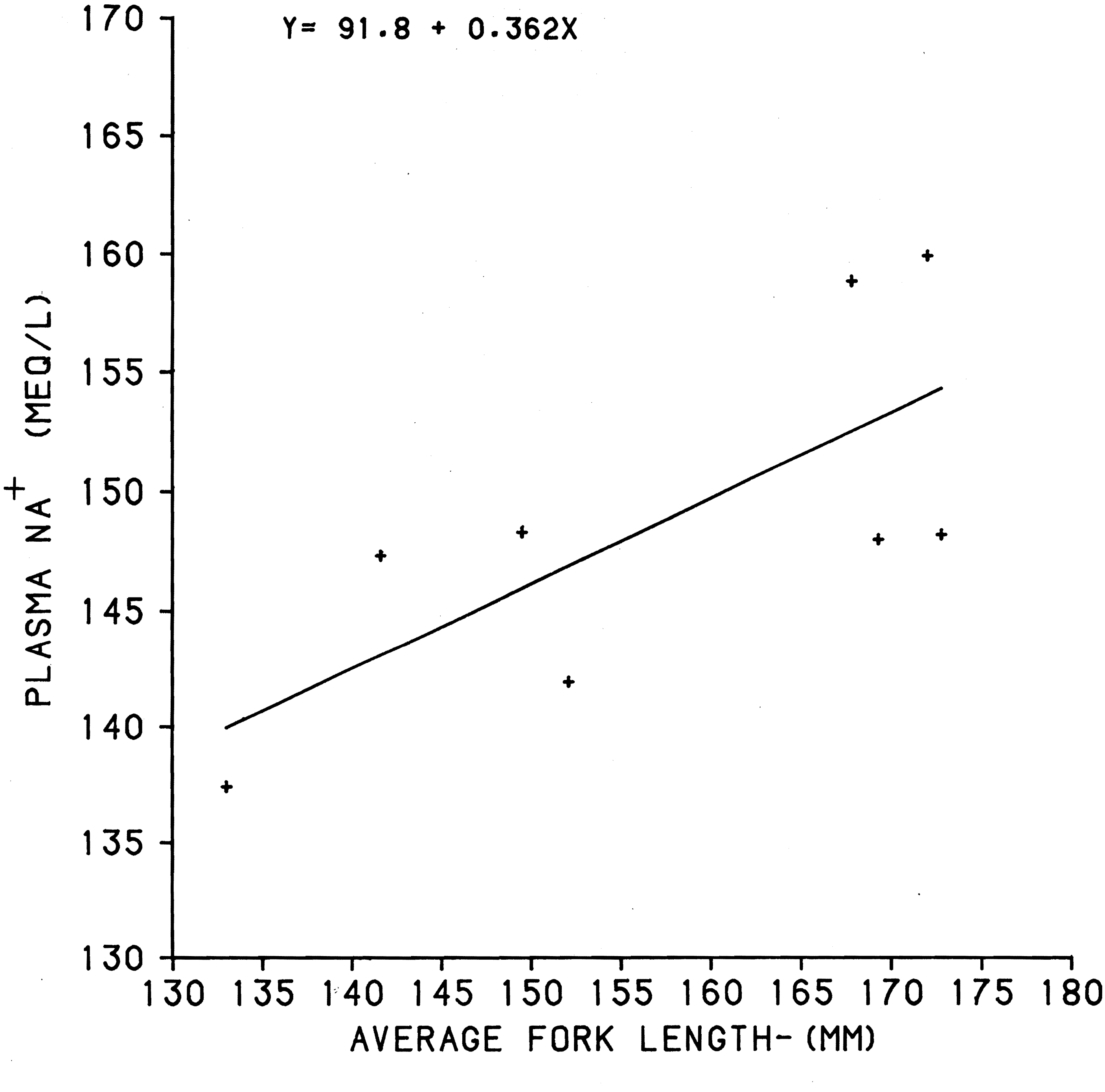


Figure 16.--Regression of average plasma Na^+ on average fork lengths for Pond 2 (Group III) Tucannon Hatchery steelhead; spring 1980. $r = 0.723$; $P < 0.05$.

seasonal dependence on these correlative factors. Conversely, MCHC and plasma K^+ were again positively correlated (Figure 17) as in Group II, throughout the season, suggesting that these values are reflections of any factors that might induce stress.

The combination of a sharp decline in gill Na^+-K^+ ATPase activity, elevation in water temperatures, and elevated plasma K^+ and MCHC values (indicating increased levels of stress), at the time Group III fish were released warrants rating the probable emigration and eventual return (as adults) much lower than Group II.

Hematology.--There were no indications of average hematological deficiencies in Group III steelhead. However, there was a small number of fish with either slightly depressed hematocrit values or values much higher than previously reported (Table 13). Average hematocrit and hemoglobin values as well as the mean cell hemoglobin concentrations rose and fell in much the same cyclical pattern, and at the same times as those in Group II. There were no significant correlations between the average hematocrit and hemoglobin levels, but in five out of eight samples the individual values were significantly correlated. In Group III steelhead, there was a significant positive correlation between average hematocrits and water temperature (Figure 18). This is inverse to the relationship found in Dworshak NFH steelhead (Figure 5), and suggests that changes in basic hematology in healthy hatchery steelhead may be a reflection of many factors.

Comments.--A subsample of 108 fish from Group III (Pond 2) were measured separately by sampling during transfer to hauling trucks on 12

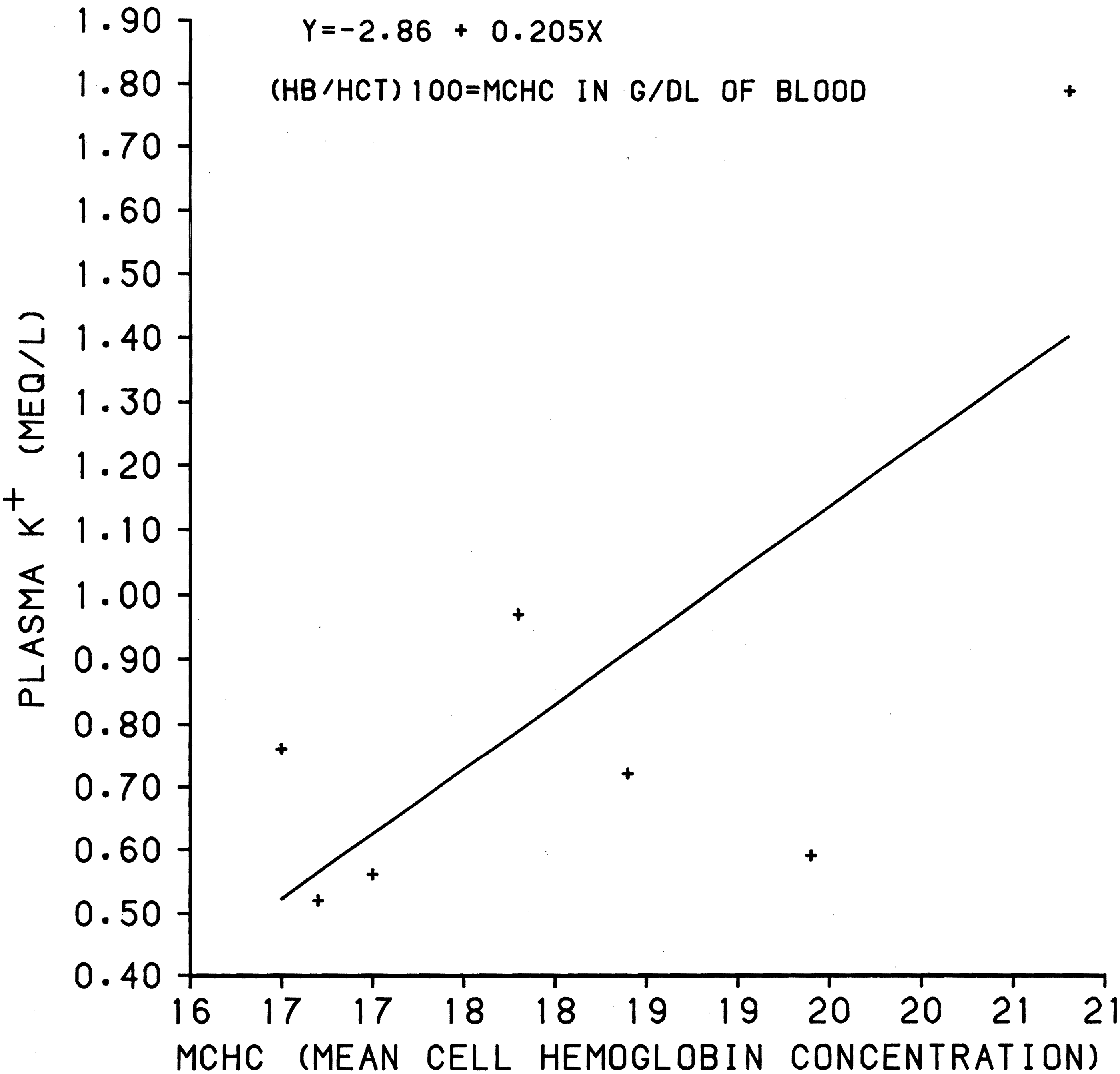


Figure 17.--Regression of average plasma K^+ on average mean cell hemoglobin concentrations (MCHC) for Pond 2 (Group III) Tucannon Hatchery steelhead, spring 1980. r =).726; P < 0.05.

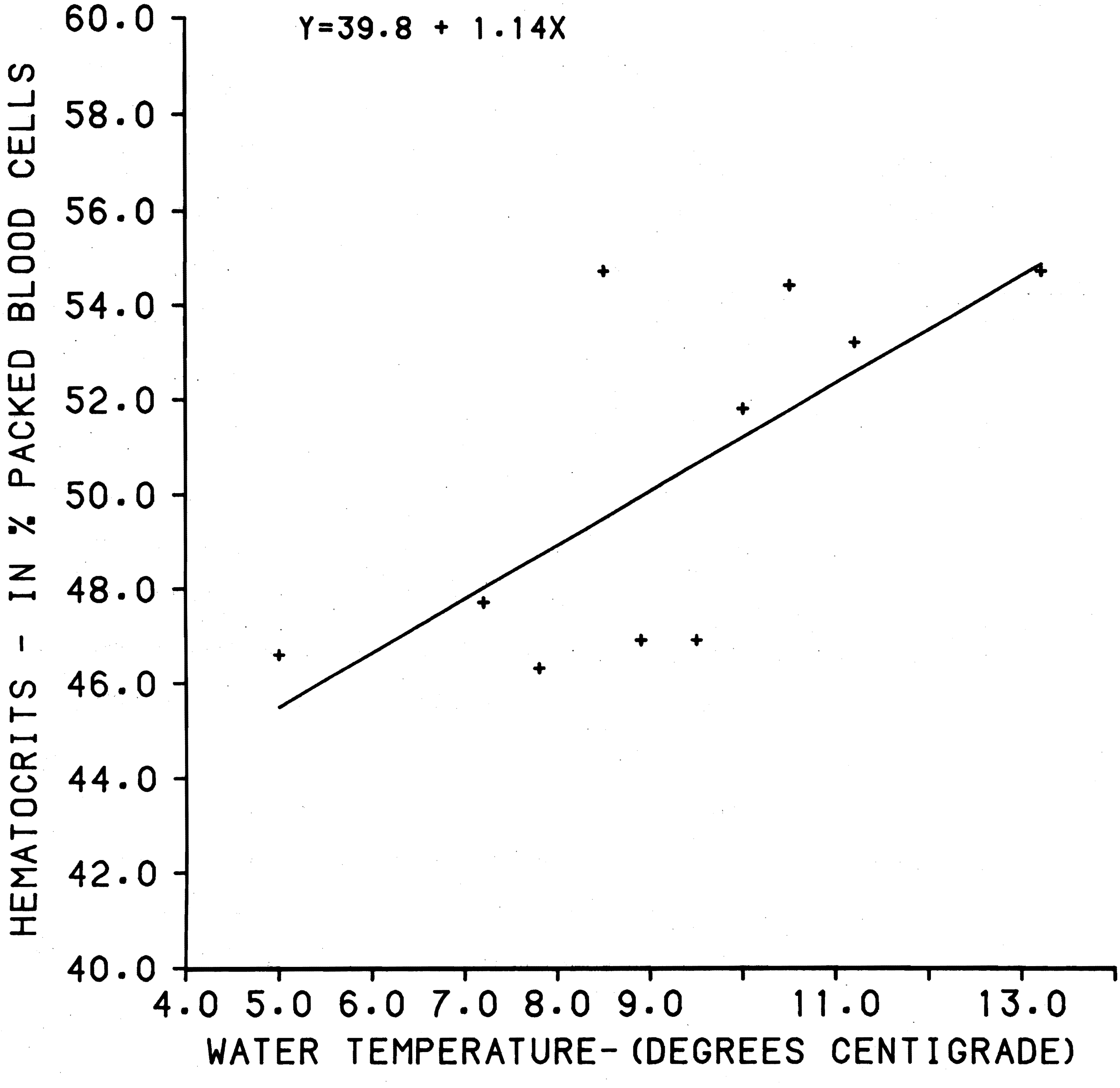


Figure 18.--Regression of average hematocrit values of Pond 2 (Group III) steelhead on the Tucannon Hatchery water temperatures during spring 1980. $r = 0.698$; $P < 0.05$.

June. The average fork length was 169.2 mm (±17.7 mm), which was not significantly different from the samples taken for health surveys on the same day (Table 13).

Group IV (Pond 5, Table 14)

Time constraints did not allow sampling this group as frequently as desired. However, summary data for Group IV (Table 14), and Figures 7 and 8 indicate that at release time (30 May), these fish were significantly smaller than any other group and had the lowest average gill Na^{+}-K^{+} ATPase values. Other parameters measured were within expected ranges. However, the data collected indicate that this Group (IV) would not be expected to emigrate or to return from the sea as well as Group II.

Summary of the Tucannon Steelhead

IFAT-BKD.--Limitations in sampling the usual 60 fish from each pond on a serial basis at the Tucannon Hatchery do not provide a good statistical base for estimating the incidence of BKD infection in the populations. Therefore, the data are presented here primarily to indicate that the incidence and intensity of infection were low (Table 17).

The greatest incidence occurred in Group III (late release) steelhead (21.7%), but the intensity of infection was still low, at between 1 and 7 (more frequently 1 to 2) organisms/150 microscopic fields (mf) examined. Therefore, BKD would not be expected to affect differential survival of these groups.

Histopathology.--Detailed summaries of the pathological conditions observed in each pond are presented in Tables 18, 19, and 20. For

Table 17.--Rate (%) and intensity of infection of BKD organisms found in the anterior and/or posterior kidneys of Tucannon Hatchery steelhead by IFAT during the 1980 sampling periods.

	Period		
	3	7	11
Date	4 April	7 May	12 June
		% of samples infected	
Group I (Pond 1)	0.0% (Released) (N=20)	---	---
Group II (Pond 4)	20.4% (N=20)	6.7% (Released) (N=30)	---
Group III (Pond 2)	5.0% (N=20)	3.3% (N=30)	21.7% (N=60)
	---	---	---
Pooled	25.4% (N=60)	10.0% (N=60)	21.7% (N=60)
Range of intensity (as no. of organisms/ 150 microscopic fields)	1 to 15	1 to 2	1 to 7

Table 18.--Pathological conditions observed in 1980 Tucannon Hatchery steelhead and their percentage of incidence[a/] (Group I, Pond 1, n = 20) (3rd period--released 4 April).

Organ and pathology	Incidence (%) Severity[b/] I	II	III	Total
Eye				
Skeletal muscle lesions	35.0	0	0	35.0
Retrobulbar fat lesions	0	5.0	0	5.0
Gills				
Increased numbers of lymphocytes	65.0	20.0	0	85.0
Epithelial cell formation	40.0	45.0	10.0	95.0
Olfactory sac				
Focal mononuclear cell infiltration	20.0	20.0	0	40.0

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

Table 19.--Pathological conditions observed in 1980 Tucannon Hatchery steelhead and their percentage of incidence [a] (Group II; Pond 4; 3rd period--released 4 April, n = 20; 7th period--released 7 May n = 30).

Organ and pathology	Incidence (%)							
	Severity[b]				Severity			
	I	II	III	Total	I	II	III	Total
Eye								
Skeletal muscle lesions	25.0	0	0	25.0	80.0	0	0	80.0
Gills								
Increased numbers of lympocytes	50.0	5.0	0	55.0	60.0	40.0	0	100.0
Epithelial cell formation	40.0	50.0	0	90.0	23.3	63.3	13.4	100.0
Vascular telangiectasis of secondary lamellae	10.0	0	0	10.0	23.3	0	0	23.3
Bacteria present	0	0	0	0	3.3	0	0	3.3
Olfactory sac								
Focal mononuclear cell infiltration	25.0	5.0	0	30.0	56.7	40.0	0	96.7
Pyogranulomatous inflammation	5.0	0	0	5.0	0	0	0	0

[a] Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

[b] I-recognizable (least severe); II-intermediate; III-severe.

Table 20.--Pathological conditions observed in 1980 Tucannon Hatchery steelhead and their percentage of incidence [a] (Group III; Pond 2; 3rd period--released 4 April, n = 20; 7th period--released 7 May, n = 30; 11th period--released 12 June, n = 60).

Organ and pathology	Incidence (%)											
	Severity [b]				Severity				Severity			
	I	II	III	Total	I	II	III	Total	I	II	III	Total
Eye												
Skeletal muscle lesions	25.0	10.0	0	25.0	80.0	0	0	80.0	70.0	0	0	70.0
Gills												
Increased numbers of lympocytes	45.0	30.0	0	75.0	76.7	16.7	0	93.4	30.0	68.3	0	98.3
Epithelial cell formation	35.0	50.0	5.0	90.0	56.7	36.7	0	93.4	43.3	46.7	6.7	96.7
Lymphatic telangiectasis of secondary lamellae	0	5.0	0	5.0	6.7	0	0	6.7	0	0	0	0
Vascular telangiectasis of secondary lamellae	5.0	5.0	0	10.0	0	0	0	0	0	0	0	0
Acute focal hemmorhage	15.0	5.0	0	20.0	0	0	0	0	0	0	0	0
Olfactory sac												
Focal mononuclear cell infiltration	30.0	10.0	0	40.0	76.7	23.3	0	100.0	40.0	58.3	0	98.3

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

comparative purposes, these data are joined and summarized in Table 9 with data from the other hatcheries.

Data collected for Tucannon Hatchery steelhead for each pond indicate comparable tissue pathology for each of the three sample periods. Sample sizes varied (for each pond) between periods as fish were released.

In the first sample (3rd period; 4 April), there appeared to be little variation in the types or frequency of occurrence (Table 18) of pathology found in steelhead from either pond. In the second sample (7th period; 7 May), pathological conditions in the remaining Groups (II and III) were comparable (Tables 19 and 20).

Comparing combined data for the sampling periods (Table 9) shows striking increases in the frequency and intensity of pathological conditions of the eye and olfactory sac, and recognizable increases in gill pathology after the first sampling (third period).

Since 1980 was the only year that serial samples were collected, comparisons of tissue pathology between years can only be made for the first week in May (Table 21). The frequency of occurrence in olfactory sac pathology doubled between 1979 and 1980, and it is remarkable that the entire incidence in 1979 was due to ciliated protozoan parasites whereas none were found in 1980. The frequency of eye lesions varied greatly for all 3 years, and gill pathology markedly increased after 1978.

Table 21.--A summarized comparison of the frequency of occurence (%) of tissue pathology observed in Tucannon Hatchery steelhead the first week in May of 1978, 1979, and 1980.

	Year		
Tissue	1978	1979	1980
Eye	57	2	80
Olfactory sac	a/	54	97
Gill			
Lymphoid	23	100	97
Epithelial	32	100	98

a/ Not available.

Hatchery records.--Information provided by the hatchery (Table 2), indicated that Formalin and malachite green (MG) were used to control periodic parasitic infestations. Our own field notes indicate that on 18 April 1980, a 24-hour 25 ppm Formalin drip treatment was started on Group II fish, followed shortly thereafter by a treatment with MG. Hyamine was used at 2 ppm for 20, 40, and 60 minutes on 29 and 31 May and 1, 7, and 8 June 1980 to control a light myxobacterial infection of the gills (Group III). Group III was also fed a TM-50 diet from 2 June to 12 June 1980.

General comments.--Group IV, smallest of the Tucannon steelhead in 1980, averaged 35 to 40 mm shorter than any other group at release time (Figure 7), and was below normal in average gill NA^+-K^+ ATPase values (Figure 8). Although other data for this group are not available, the below normal size and low average Na^+-K^+ ATPase values indicate that survival and returns from this group will be low. Field notes indicated that fish over 150 mm in fork length appeared smolted.

Our field notes of visual observations indicate that most fish in Groups II and III below 170 mm in fork length were still parred in mid-April, and by the first week in May, Group II was smolting rapidly, with Group III about 1 week later. By mid-May, steelhead greater than 163 mm ($\pm$3 mm) in fork length in Group II appeared smolted.

Key physiological indicators of migratory readiness, gill Na^+-K^+ ATPase and plasma Na^+ and Cl^-, were in the smolt indicating segments of their respective profiles between the first and third weeks in May for Group III fish. By the time of release, these indications had disappeared, and there was a sharp increase in possible stress indicators, plasma K^+ and MCHC. Although the incidence of tissue pathology did not increase between May and early June, the requirements of additional therapeutic treatments could increase the stress factors for Group III. The analyzed data indicate that Group III fish were probably in a post-smolt condition (regardless of size) by 12 June, and that all of these factors will have a negative influence on their survival and return. Correlations between fish size and gill Na^+-K^+ ATPase at the time of release were poor, and no prognosis on percentages of expected migration should be made.

Group II fish represented the normal early May release (as in 1978 and 1979), which, in 1980, occurred at the probable peak activity of one of the main smolting indicators, gill Na^+-K^+ ATPase (Figure 8), but about 3 weeks after the maximum deviation of plasma Na^+ and Cl^- (Table 12). Stress indicators (plasma K^+ and MCHC) were low at release and good positive correlations between gill Na^+-K^+ ATPase and fork lengths just prior to release suggest that at least 50% of the group were in a good state of migratory preparedness.

There were no correlations for the earliest Group (I) released between gill Na^{+}-K^{+} ATPase and other parameters measured that would aid in prognosis of comparative survival or expected smolt indexing, but it is quite clear that their physiological condition was much different than Group III fish at release. In Group III (12 June), mean Na^{+}-K^{+} ATPase activity (Figure 8) and variance (Table 13) was low, indicating that regardless of size, the fish were in a post-smolt condition. However, in Group I, at release (10 April), the mean Na^{+}-K^{+} ATPase was elevated (Figure 8), and the variance was large (Table 11). The lack of correlation between fish size and Na^{+}-K^{+} ATPase suggests that smolting was occuring regardless of size. We indicated that over 80% of the normal release Group (II) samples (Figures 10 and 11) and 90% of Group I samples (Figure 19) had Na^{+}-K^{+} ATPase values greater than 10 at the time of release (7 May). Furthermore, plasma Na^{+} had reached maximum and plasma Cl^{-} had reached mininum values at the time of release (Group I, Table 11). The incidence of any tissue pathology was lowest in Group I at time of release (Tables 9 and 18), and average size was quite close to that of other major release groups (Figure 7). All of these factors combined suggest that the early release group may have had a fair migratory development.

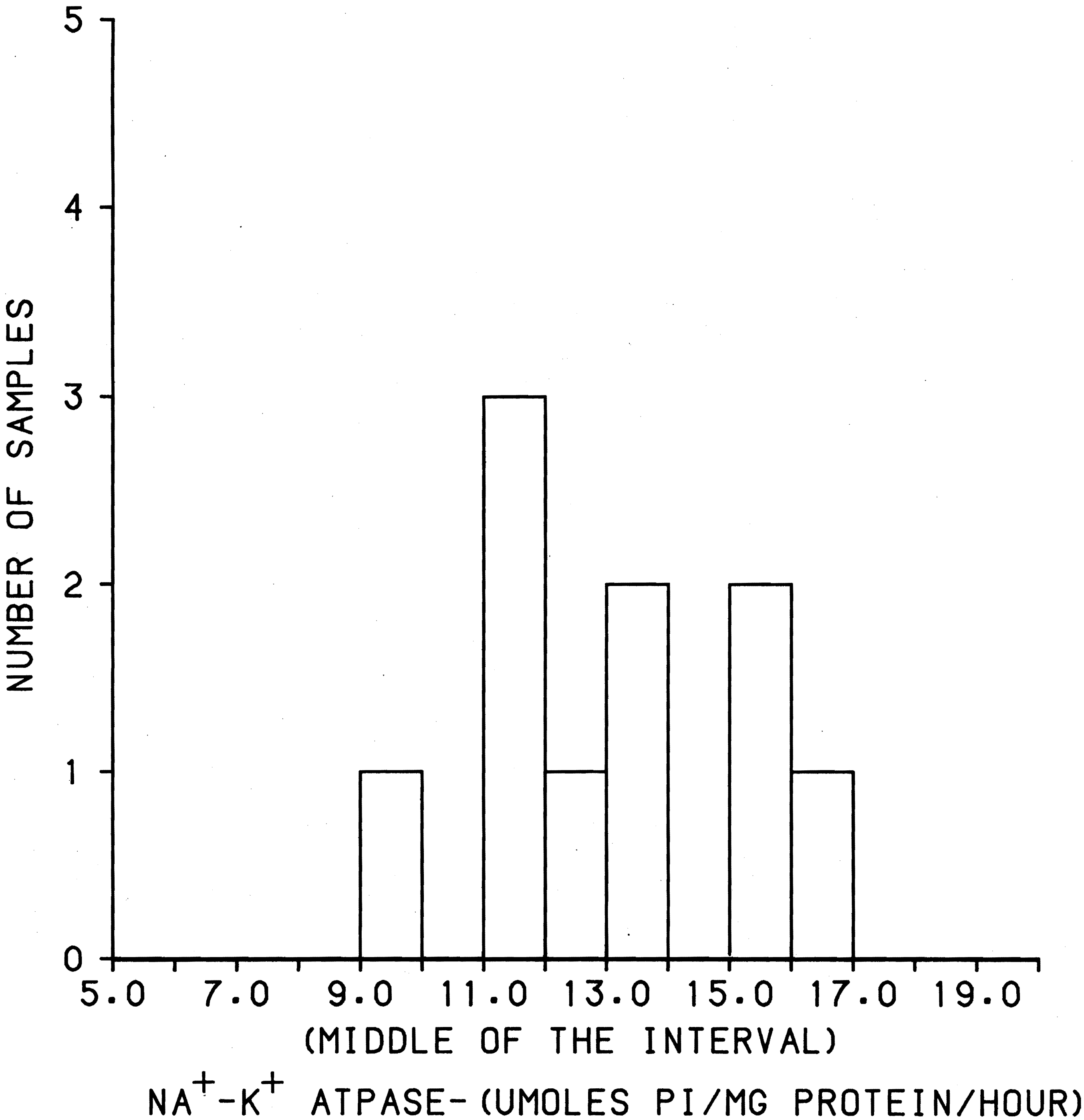


Figure 19.--Frequency histogram of the average gill Na^{+}-K^{+} ATPase values of Group I Tucannon Hatchery steelhead at the time of release (10 April 1980).

RESULTS AND DISCUSSION OF SPRING CHINOOK SALMON SURVEYS

Leavenworth National Fish Hatchery

General

Two sampling trips to Leavenworth NFH were made in late 1979 (Table 22) primarily to test procedures and to sample during a fall marking test. We began collecting full data in March of 1980, and sampling continued into early June. Until early April, the fall-mark group was cultured in colder (Icicle Creek) water. For example, on the first trip in March, water temperature was 3.0°C for the fall-mark group and 6.1°C in the other ponds.

There were 16 different tagged groups that were released under varying conditions between 17 April and 1 May 1982, the bulk of which were released between 24 April and 1 May. Data collected primarily from one normal pond (#17) and the fall-mark group in late 1979 are presented in Table 22.

Sampling period days are presented with 1 January 1980 as Day +1 and 31 December 1979 as Day -1 to simplify computer programming, and are presented in Table 22 along with the calendar dates for each sampling period. In the fifth period (23 April), samples were collected from Pond 17 and other test groups primarily for Na^{+}-K^{+} ATPase analysis, and these data are presented elsewhere. Sample sizes were reduced to 30 fish/test group in this period.

Figure 20 shows the water temperatures measured at the hatchery at each sampling period in 1980. Temperatures between November 1979 and March 1980 are not shown.

Leavenworth NFH spring chinook salmon were not used for homing experiments in 1978 or 1979, but they were included in a smolt evaluation

Table 22.--Summary data for 1978 brood spring chinook salmon samples collected at Leavenworth National Hatchery in late 1979 and in the spring of 1980, with means, standard deviations ( ), and ranges. Sample size = 60 except for the 5th Period (n=30).

Item	Period										
	A	B	1	2	3	4	5	6	7	8	9
Date	1 Nov 79	14 Nov 79	3 Mar 80	17 Mar 80	31 Mar 80	14 Apr 80	23 Apr 80	28 Apr 80	12 May 80	29 May 80	17 June 80
Days>Ja1 a/	-61	-47	63	76	90	104	113	118	132	149	168
Temp. °C b/	3.0	2.1	6.1	4.5	4.0	6.8	6.1	5.5	6.0	8.0	9.5
Avg. Fk Ln c/	110.3	112.5	124.8	123.7	136.2	130.4	129.1	132.7	133.4	137.7	140.3
	(10.8)	(11.9)	(16.1)	(12.0)	(18.1)	(12.8)	(8.7)	(13.2)	(10.6)	(15.1)	(10.7)
(Range)	92-141	85-145	98-172	97-152	106-188	109-164	112-152	106-166	108-162	118-183	126-176
Avg. ATP Fk Ln d/	---	---	124.4	124.7	135.2	124.3	129.1	134.6	134.0	138.7	142.4
	---	---	(8.1)	(6.8)	(7.5)	(6.4)	(6.0)	(13.0)	(10.5)	(13.7)	(9.4)
(Range)	---	---	117.0-143.3	117.3-133.7	127.3-150.3	114.7-132.7	121.3-140.7	119.7-164.3	115.0-146.7	121.3-164.0	132.3-156.3
Avg. ATP e/	---	---	7.0	7.2	10.6	9.3	7.7	12.5	13.7	13.2	10.1
	---	---	(1.3)	(1.2)	(1.4)	(1.1)	(1.4)	(2.2)	(1.6)	(3.1)	(3.3)
(Range)	---	---	5.4-9.4	5.6-9.9	8.3-12.6	7.8-11.6	5.7-10.6	9.2-16.3	11.5-15.8	7.3-19.4	4.6-15.1
Avg. Hct f/	40.2	47.8	46.5	43.6	39.8	41.1	39.6	40.6	34.2	33.5	30.5
	(4.8)	(6.0)	(6.7)	(6.6)	(8.1)	(8.3)	(5.7)	(10.0)	(8.9)	(8.1)	(7.9)
(Range)	31-51	37-71	27-60	24-59	17-56	15-60	25-50	19-64	16-54	13-56	8-48
Avg. Hb g/	6.5	7.5	6.6	6.5	6.8	6.1	---	5.9	5.5	5.2	5.0
	(0.6)	(0.8)	(1.1)	(1.5)	(1.6)	(1.4)	---	(1.4)	(1.6)	(1.6)	(1.7)
(Range)	5.0-7.7	4.7-9.0	3.7-9.3	2.0-9.7	2.9-9.7	1.7-9.0	---	3.2-8.7	2.3-8.7	1.0-10.0	1.3-8.3
Avg. MCHC h/	16.4	15.9	14.2	14.9	17.0	14.9	---	14.7	16.2	15.4	16.1
	(1.6)	(1.8)	(1.1)	(3.5)	(1.9)	(1.8)	---	(1.8)	(2.3)	(3.2)	(2.6)
(Range)	13.4-19.7	9.5-20.0	11.1-16.6	4.4-30.3	13.0-21.1	9.1-18.2	---	10.8-18.8	11.0-21.2	6.7-25.6	8.9-22.4
Avg. Na^+ i/	---	---	150.8	146.5	146.6	154.6	---	155.2	155.6	143.4	136.8
	---	---	(11.9)	(14.3)	(12.9)	(4.9)	---	(8.1)	(7.7)	(11.0)	(10.9)
(Range)	---	---	132-180	117-169	119-167	144-165	---	134-165	140-185	85-159	104-156
Avg. K^+ j/	---	---	0.65	0.69	0.56	1.25	---	0.88	0.47	0.96	1.99
	---	---	(0.60)	(0.41)	(0.26)	(0.77)	---	(0.66)	(0.25)	(0.88)	(1.23)
(Range)	---	---	0.32-2.7	0.40-2.3	0.33-1.24	0.47-2.85	---	0.20-2.70	0.21-1.06	0.15-4.04	0.21-4.8
Avg. Cl^- k/	---	---	133.6	136.8	134.0	131.4	---	134.5	129.1	118.7	130.4
	---	---	(12.8)	(10.3)	(15.6)	(6.0)	---	(7.4)	(11.8)	(10.3)	(9.4)
(Range)	---	---	122-166	124-155	106-158	120-144	---	15.0-145.0	103-169	87-135	112-155
Na^+/Cl^- l/	---	---	1.13	1.08	1.10	1.18	---	1.16	1.21	1.23	1.05
	---	---	(0.09)	(0.12)	(0.10)	(0.06)	---	(0.03)	(0.10)	(0.10)	(0.10)
(Range)	---	---	1.02-1.34	0.79-1.28	0.83-1.25	1.05-1.29	---	1.10-1.21	1.07-1.56	1.02-1.61	0.74-1.29

a/ Days>Ja1: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

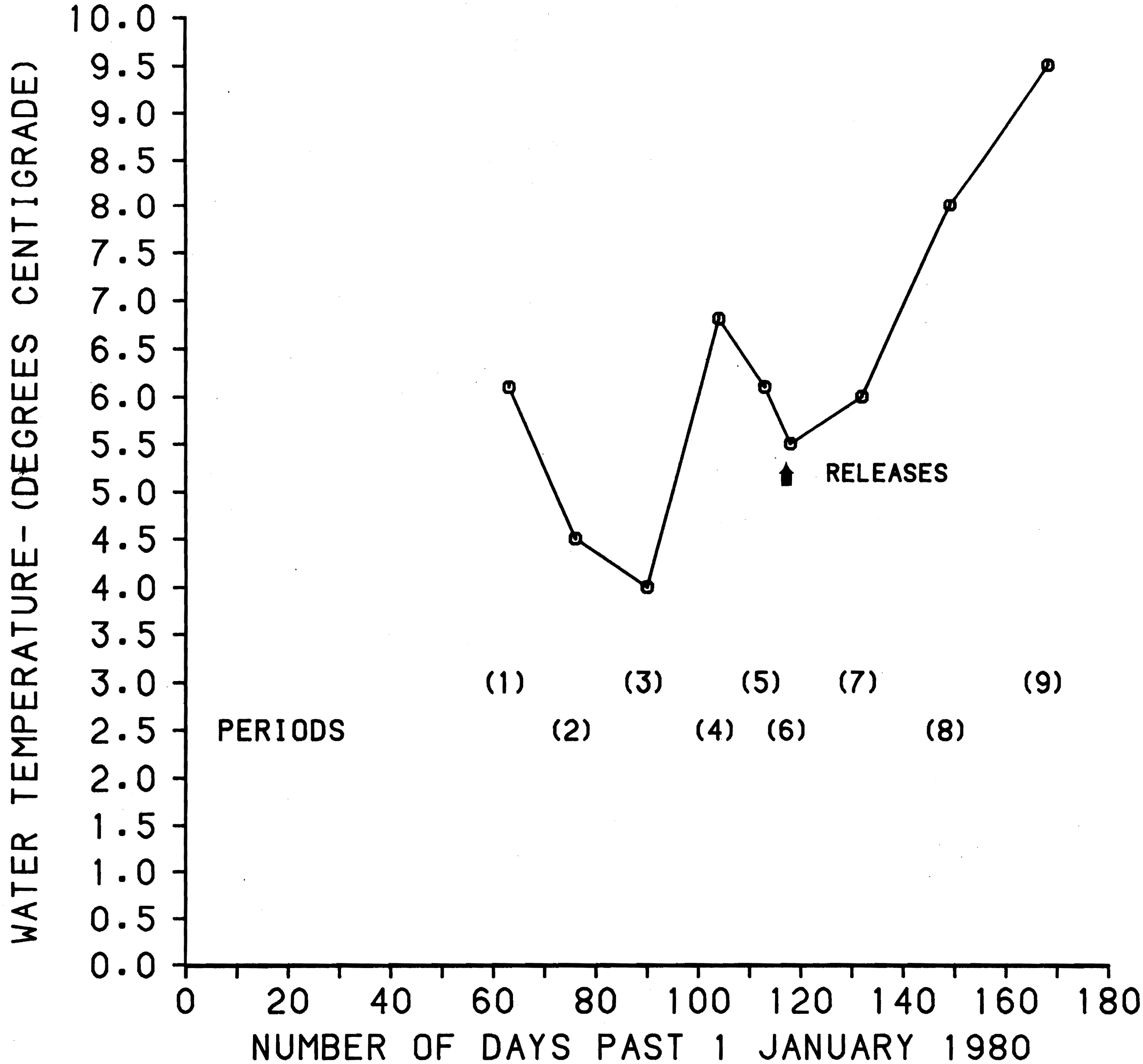


Figure 20.--Water temperatures of the outdoor raceways at Leavenworth NFH during spring 1980.

study (Anon 1979; Prentice et al. 1980). Mean fork lengths of samples collected from the various test groups released during the fifth period (23 April) ranged from 121.9 to 134.6 mm (Table 23). There was a significant difference (P = 0.02) between mean length of the fall-mark group (II) and the controls (III) in 1980 (Table 23). Mean lengths of samples collected at release were 138 and 139 mm in 1978 (25 April) and 131 mm in 1979 (24 April).

Gill Na^{+}-K^{+} ATPase

In 1978, gill Na^{+}-K^{+} ATPase values peaked in early April, stabilized through April, and began a gradual decline in early May (Figure 21, Anon 1979). The profile in 1979 was almost identical to that of 1980 with the exception of a temporary decline in 1980 the first 3 weeks in April (Figure 21). The range of values was similar for the 3 years. In 1980, the releases were ongoing during the period of maximum Na^{+}-K^{+} ATPase rise (Figure 21). Manipulations of water temperatures (by mixing Icicle River water and well water) and/or changes in ponding procedures may have had some effect on the Na^{+}-K^{+} ATPase profiles between years.

The summary gill Na^{+}-K^{+} ATPase data collected shows substantial differences in mean values among the various groups at the time of release (Table 23). There was a significant difference (P = 0.006) between mean Na^{+}-K^{+} ATPase values of Group III (considered controls), and means of Group I (by-pass channel Group); between Groups III and II, the fall-mark group (P = 0.013); and between Groups III and IV, the channel control (P = 0.0000).

We also examined relationships between mean fork lengths of pooled fish used for Na^{+}-K^{+} ATPase analysis and gill Na^{+}-K^{+} ATPase values

Table 23.--A summary of basic data collected from representative samples of various release groups of Leavenworth Hatchery spring chinook salmon (23 April 1980).

Parameter	Representative Group I	II	III	IV
Fork length				
Means	130.0	121.9	129.1	134.6
S.D.	(13.1)	(14.2)	(8.7)	(14.6)
Range	113-168	102-156	112-152	116-180
N	(30)	(30)	(30)	(30)
Hematocrits				
Means	41.4	31.1	39.6	34.2
S.D.	(6.4)	(9.1)	(5.7)	(7.1)
Range	23-50	3-43	25-50	13-46
N	(29)	(26)	(28)	(28)
Gill Na^{+}-K^{+} ATPase				
Means	10.3	9.7	7.7	11.1
S.D.	(2.3)	(1.8)	(1.4)	(1.8)
Range	7.4-15.9	7.3-13.7	5.7-10.6	8.8-15.7
N	(10)	(10)	(10)	(10)

I = Typical bypass channel test group.
II = Fall-mark group (Pond 46).
III = Normal (Pond 17)
IV = Channel control group.

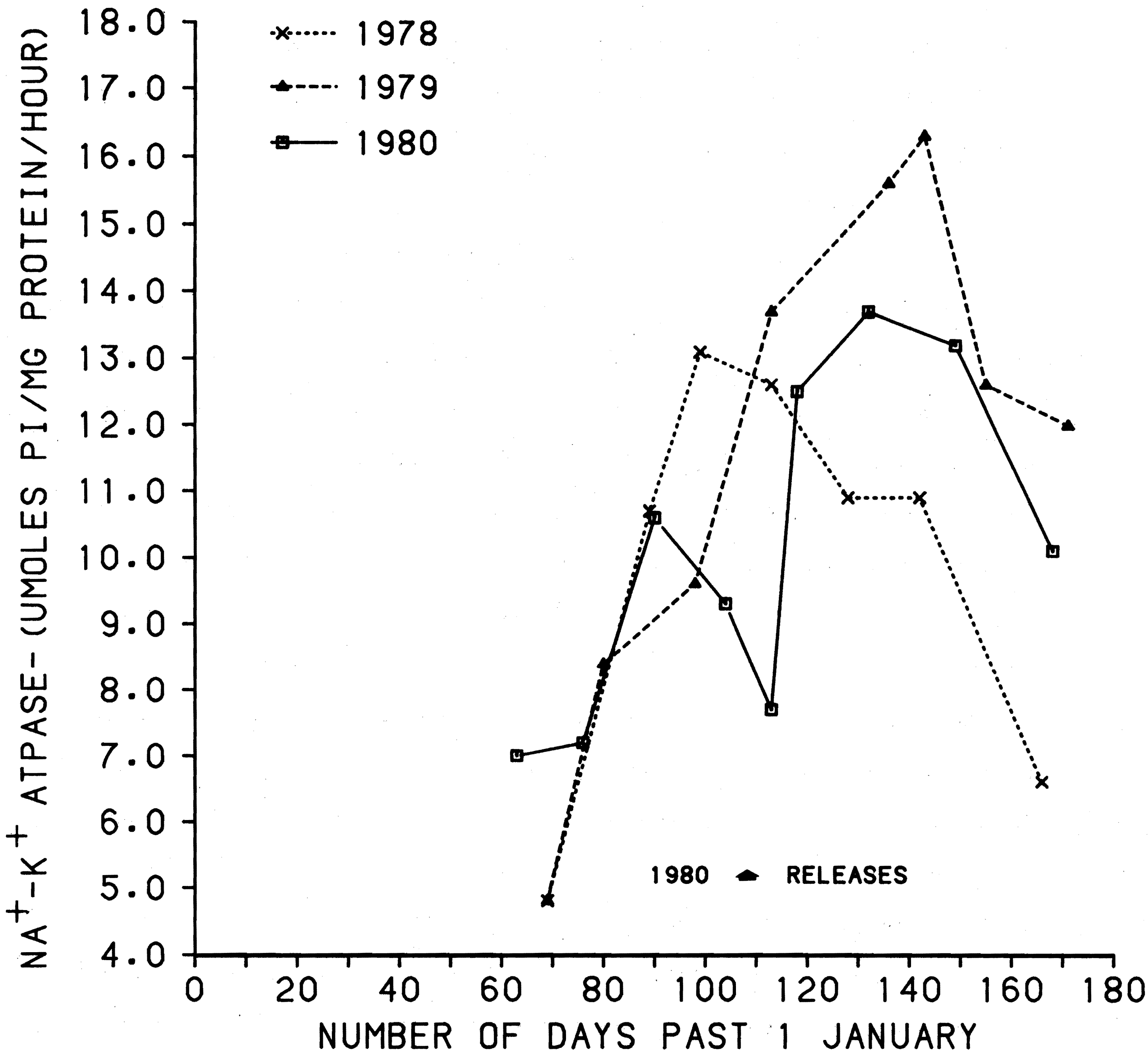


Figure 21.--Average gill Na^+-K^+ ATPase values for the Leavenworth NFH spring chinook salmon during the 1978-1979 smolt and 1980 homing studies.

at each sampling as a possible source of group differences in Na^+-K^+ ATPase values. However, the only significant correlations were in the control fish (Pond 17), which occurred during periods of maximum gill Na^+-K^+ ATPase increase, 23 April to 28 April (Table 24). Length data for the fish sampled for Na^+-K^+ ATPase are shown in Table 22 and profiled in Figure 22.

There was a significant correlation ($P < 0.05$) between the mean fork length of fish collected for Na^+-K^+ ATPase analysis in Pond 17 (control) and the mean gill Na^+-K^+ ATPase during the 1980 sampling period (Figure 23). Since there was also a significant correlation between the mean fork lengths of pooled fish and measured Na^+-K^+ ATPase values during the April 23-28 period in normal fish (Pond 17) (Table 24), and this period was one of maximum Na^+-K^+ ATPase increase, the data in Figure 21 suggest that fish with Na^+-K^+ ATPase values of 10.5 or more should have been smolting at the time of release. A regression analysis of samples from the fifth and sixth sampling periods are shown in Figure 24. Since most of the fish were released between 23 April and 28 April, a theoretical regression line of gill Na^+-K^+ ATPase and fork lengths typifying this period has been drawn in. It suggests that any fish $\geq$ 132 mm (Na^+-K^+ ATPase of 10.5) should have been smolting. The percentage of fish with gill Na^+-K^+ ATPase $\geq$ 10.5 increased from 10 to 78%, and the percentage of fish $\geq$ 132 mm increased from 37 to 45% between 23 April and 28 April. On the basis of this information, it would be reasonable to assume that between 40 and 50% of the normal (control) release groups were probably smolting at the time of release. Although fork lengths and gill Na^+-K^+ ATPase values in the other marked release

Table 24.--Correlation coefficients for gill Na^{+}-K^{+} ATPase, fork length, and hematological parameters for 1980 Leavenworth Hatchery spring chinook salmon.

	Sampling 1980 program											
					23 April group							
Parameters	3/3	3/17	3/31	4/14	I	II	III	IV	4/28	5/12	5/29	6/17
Ln x Hct	-0.070	0.123	-0.195	0.299	0.150	-0.615	0.363	0.306	-0.309	0.002	-0.051	-0.121
D.F.	58	58	57	58	27	24	26	26	58	57	58	58
P				<0.05		<0.001			<0.05			
Hct x Hb	0.891	0.416	0.876	0.868	-	-	-	-	0.878	0.882	0.761	0.894
D.F.	58	57	57	58	-	-	-	-	58	57	58	58
P	<0.001	<0.005	<0.001	<0.001	-	-	-	-	<0.001	<0.001	<0.001	<0.001
Ln x Hb	0.073	0.364	0.032	0.417	-	-	-	-	0.163	0.160	0.053	-0.135
D.F.	58	57	57	58	-	-	-	-	58	58	58	58
P		<0.01		<0.005								
Ln x MCHC	0.310	0.264	0.456	0.335	-	-	-	-	0.342	0.364	0.128	-0.061
D.F.	58	57	57	58	-	-	-	-	58	57	58	58
P	<0.05		<0.001	<0.02	-	-	-	-	<0.02	<0.01		
Mfl x ATP	0.295	0.197	0.109	0.527	-0.254	-0.323	0.700	0.346	0.729	-0.345	-0.475	0.384
D.F.	8	8	8	8	8	8	8	8	8	8	8	8
P							<0.05		<0.02			
MHct x ATP	-0.020	0.497	0.112	0.072	-0.010	0.211	0.453	0.146	-0.471	0.496	0.045	-0.524
D.F.	8	8	8	8	8	8	8	8	8	8	8	8
P												
MHb x ATP	0.156	0.285	0.095	0.290	-	-	-	-	-0.325	0.212	0.298	-0.606
D.F.	8	8	8	8	-	-	-	-	8	8	8	8
P												
MCHC x ATP	0.334	-0.054	-0.020	0.483	-	-	-	-	0.501	-0.415	0.364	-0.573
D.F.	8	8	8	8	-	-	-	-	8	8	8	8
P												

Nomenclature:

Fk Ln = fork length
Hct = hematocrit
Hb = hemoglobin
MCHC = mean cell hemoglobin concentration
Mfl = mean fork lengths for the 3 fish pools used for ATPase
MHct = mean hematocrits for the 3 fish pools used for ATPase
MHb = mean hemoglobins for the 3 fish used for ATPase
MCHC x ATP = average mean cell hemoglobin concentration for the 3 fish pools used for ATPase
ATP = Na^{+}-K^{+} fill ATPase value for each pool of 3 fish
D.F. = degrees of freedom
P = probability

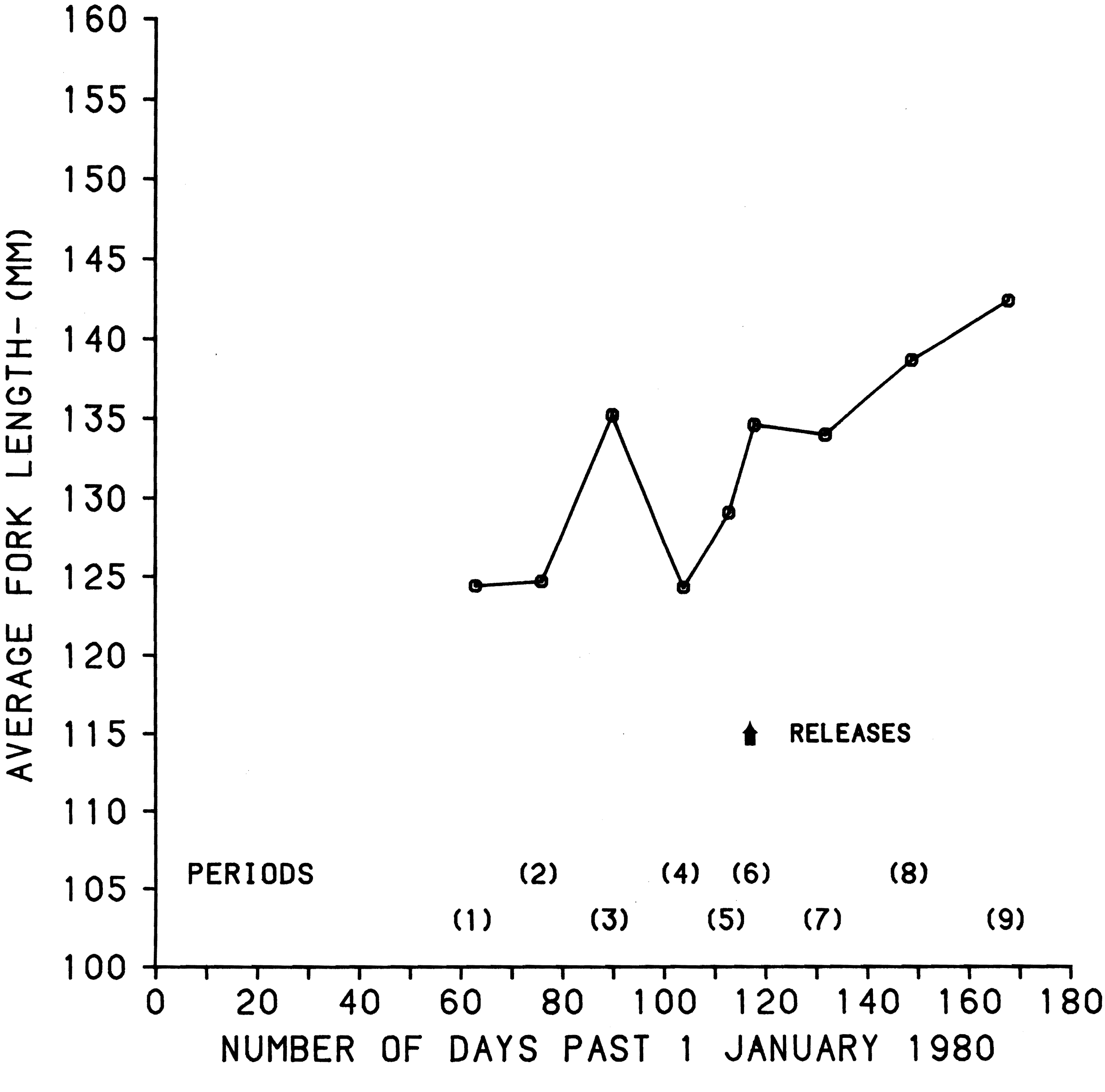


Figure 22.--Mean fork lengths of the spring chinook salmon from Leavenworth NFH used for gill Na^+-K^+ ATPase analyses in spring 1980.

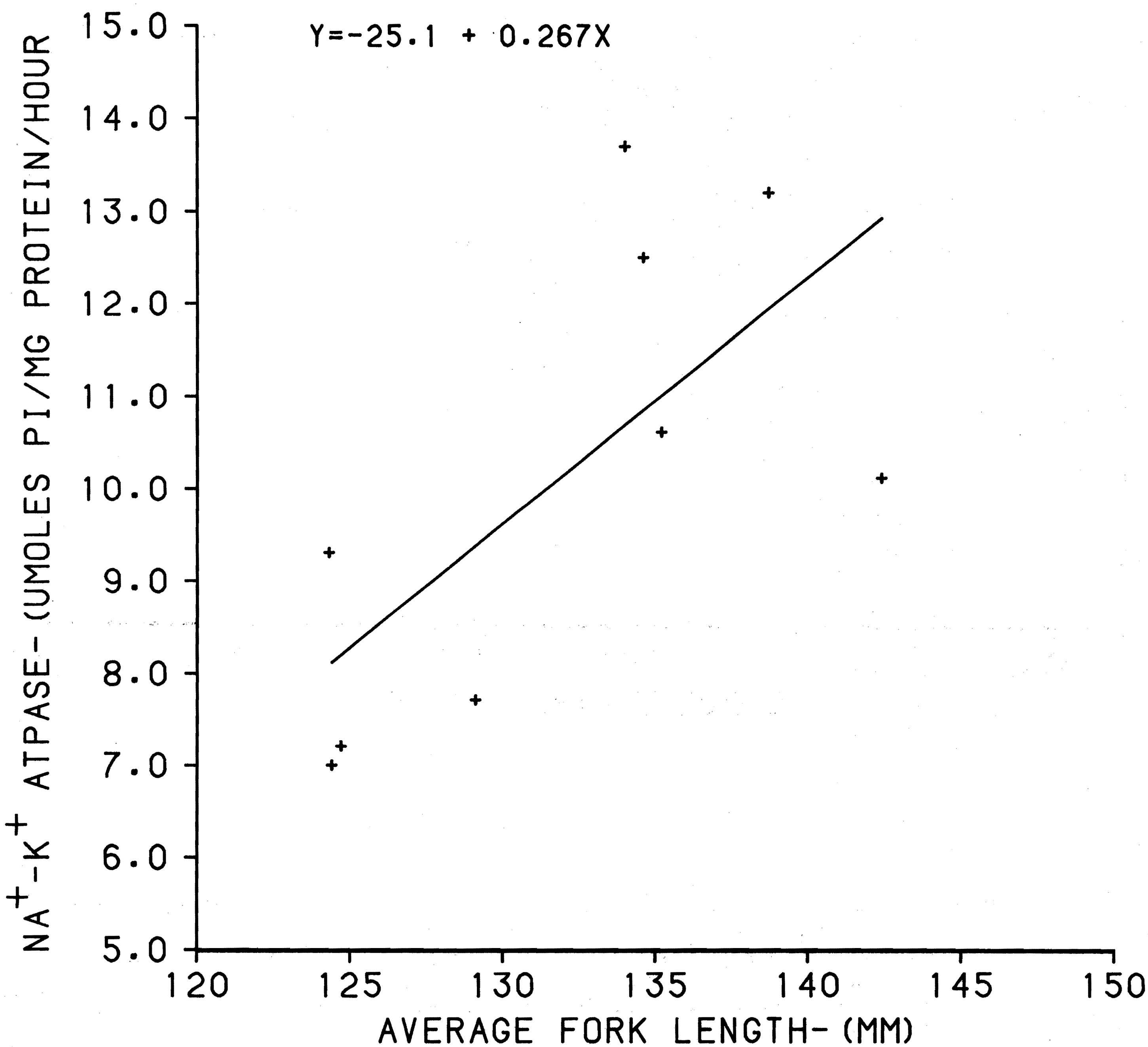


Figure 23.--Regression of the average gill Na^+-K^+ ATPase values on average fork lengths of fish pooled for Na^+-K^+ ATPase analysis (Leavenworth NFH spring chinook salmon - spring 1980). r = 0.689; $P < 0.05$.

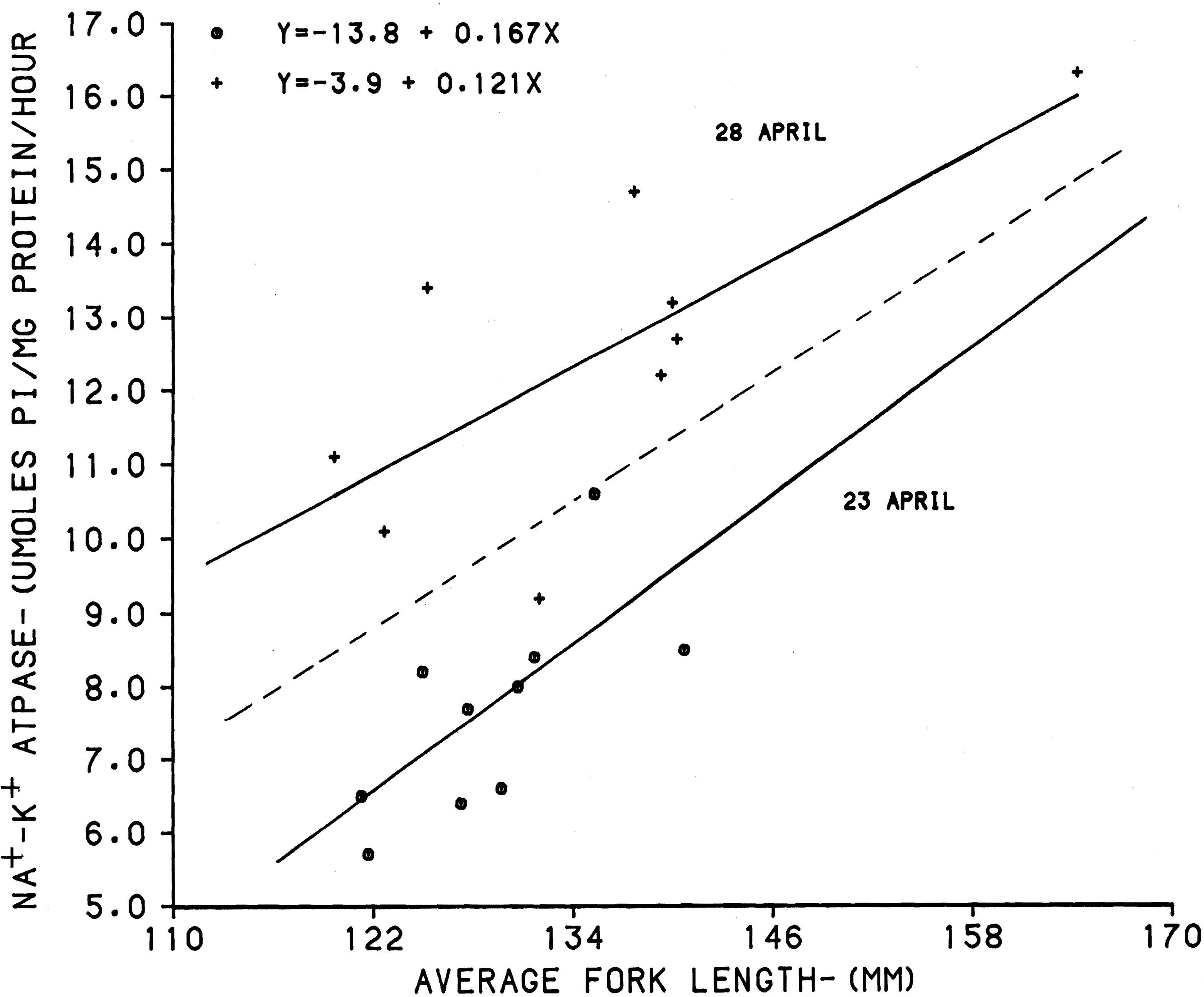


Figure 24.--Regression of gill Na^{+}-K^{+} ATPase values on 23 April and 28 April 1980 on average fork lengths of spring chinook salmon pooled (3 fish/pool) for Na^{+}-K^{+} ATPase analysis at Leavenworth NFH. $r = 0.699$; $P < 0.05$ for 23 April. $r = 0.729$; $P < 0.05$ for 28 April. A theoretical line (------) has been drawn in for a period halfway between 23 April and 28 April.

groups could not be correlated, Na^+-K^+ ATPase values $\geq$ 10.5 ranged from 30 to 50%. On the basis of this information, we suggest that there may have been differences in the migratory readiness of the normal (Pond 17) and other marked groups.

Plasma Electrolytes

There are few published data on normal plasma electrolyte levels in hatchery chinook salmon. Table 25 is a summary of the mean plasma Na^+, Cl^-, and K^+ values from chinook salmon that we examined previously. The exceptionally high K^+ values in the Kalama Hatchery spring chinook salmon may be due to hemolysis that occurred after sampling.

Mean plasma electrolyte values for Leavenworth NFH spring chinook salmon sampled in the spring of 1980 were generally within expected ranges throughout the season and at the time of release (Table 22). Average plasma Na^+ reached peak levels at the time of release and declined rapidly from mid-May on (Table 22). Average plasma Cl^- values were somewhat more erratic, but followed the same general decline as mean plasma Na^+. Maximum deviation of plasma Na^+ and Cl^- (Na^+/Cl^- ratio) occurred just prior to and after the release period (Table 22).

Significant correlations between individual plasma Na^+ and Cl^- occurred frequently throughout the sampling periods (Table 26), and were highly significant ($P < 0.001$) between the sixth and eighth periods (28 April through 29 May). There were significant negative correlations between the plasma Cl^- and the Na^+/Cl^- ratios (Table 27) throughout the sampling season (with one exception; the sixth period - 28 April), and they were most highly significant ($P < 0.001$) throughout May. This is a

Table 25.--Mean values of plasma Na^+, Cl^-, and K^+ from other samplings of hatchery chinook salmon.

Sample	Millequivalents/l		
	Na^+	Cl^-	K^+
1978 Kalama Falls Hatchery spring chinook salmon (at release)	137	116	11.9[a]
1978 Kooskia Hatchery spring chinook salmon (at release)	114	104	---
1978 Leavenworth Hatchery spring chinook salmon (at release)	150	108	1.7
1979 Leavenworth Hatchery spring chinook			
March	158	129	3.0
At release (late April)	149	125	0.8
June	148	130	2.3
1979 Carson Hatchery spring chinook salmon (at release)	146	134	3.7

[a] These were abnormally high potassium values, and may have been due to some hemolysis of the samples.

Table 26.--Correlation coefficients between plasma Na^+ and Cl^- for each sampling period in 1980 for Leavenworth Hatchery spring chinook salmon.

Item	Period							
	1	2	3	4	6	7	8	9
Correlation coefficients	0.64[a]	0.10	0.62[a]	0.03	0.91[a]	0.55[a]	0.49[a]	0.18

[a] Significant ($P < 0.05$)

Table 27.--Correlation coefficients between plasma Cl^- values and individual Na^+/Cl^- ratios for each sampling period in 1980 for Leavenworth Hatchery spring chinook salmon.

Item	Period							
	1	2	3	4	6	7	8	9
Correlation coefficients	-0.60[a]	-0.55[a]	-0.70[a]	-0.82[a]	-0.21	-0.81[a]	-0.82[a]	-0.59[a]

[a] Significant ($P < 0.05$)

reflection of a rapid decline in plasma Cl^-, and coincides with a period of peak gill Na^+-K^+ ATPase activity (Table 22).

Mean plasma K^+ values (Table 22) were frequently lower than reported values that we have available (Table 25), but again this may be a reflection of our hemolysis ranking program and/or stresses induced by transporting in 1978 and 1979. Mean plasma K^+ values peaked just prior to release and then declined until mid-May. Increases in mean plasma K^+ after mid-May may be due to holding the fish past the normal time of migration and a reflection of smolting stresses and increasing water temperatures. Plasma K^+ was the only electrolyte that we could significantly correlate with water temperature (Figure 25).

Hematology

Unpublished data from salmon diet studies in Oregon indicate expected mean hematocrits for spring chinook salmon ranging from 24.2 to 38.0% and 35 to 39% for fall chinook salmon. Published data on small fall chinook salmon fingerlings (Banks et al. 1971) indicate that hematocrit and hemoglobin values increase as the water temperature increases (Table 28).

Mean values of fall and spring chinook salmon sampled in 1978 and 1979, with one exception, ranged from: (1) hematocrits--34.9 to 59.4% and (2) hemoglobins--5.2 to 8.9 g Hb/dl blood. The one exception was a group of yearling fall chinook salmon in 1979 at Willard NFH with mean hematocrits of 26.5% and mean hemoglobins of 3.2 g Hb/dl blood. Over 56% of the samples from these fish were classified as positive for bacterial kidney disease (BKD). Hematocrit values below 28% in Pacific salmon may be indicative of a number of health problems and should signal a cautionary warning.

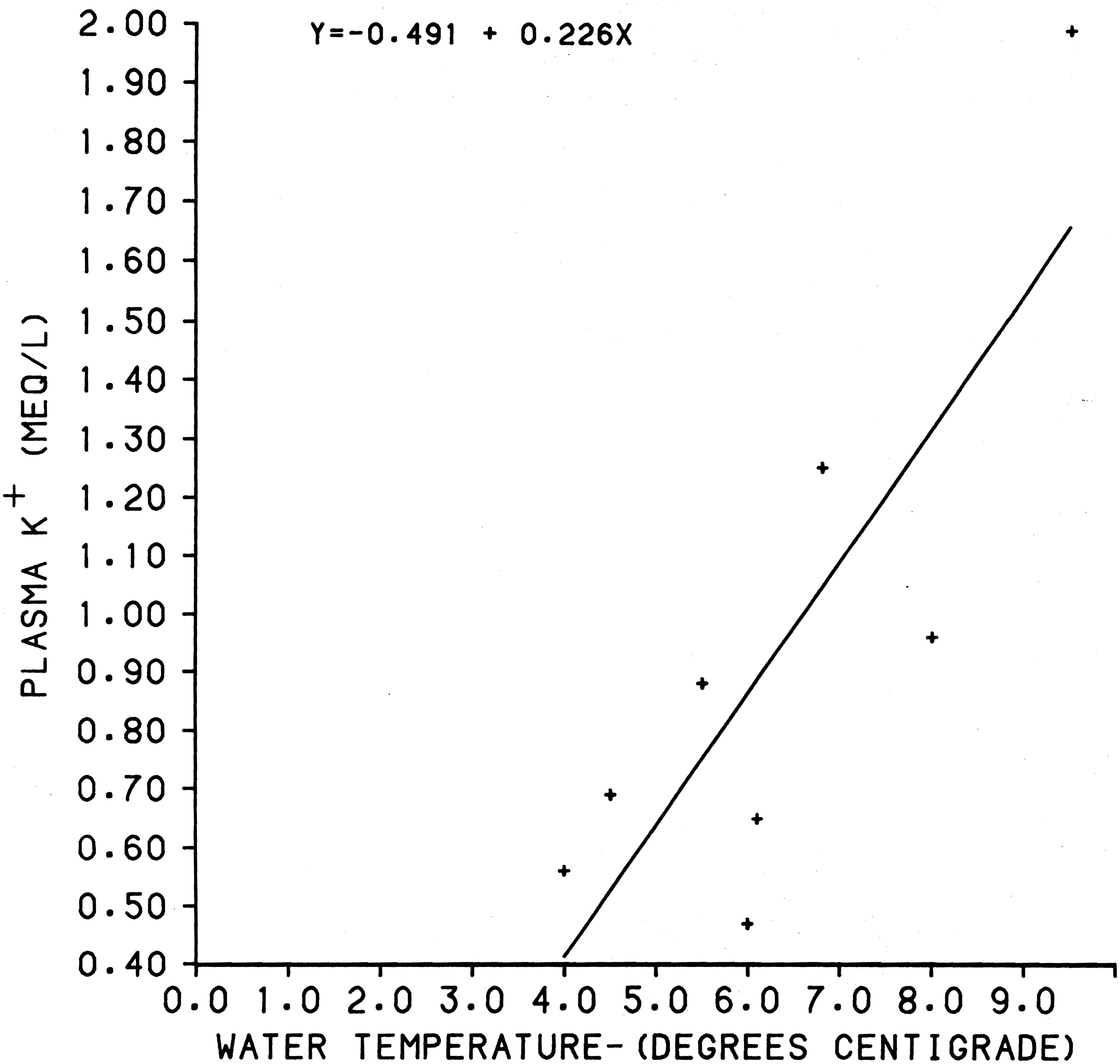


Figure 25.--Regression of the average plasma K^+ on water temperature for Leavenworth NFH spring chinook salmon during spring 1980. $r = 0.821$; $P < 0.02$.

Table 28.--Hematocrit and hemoglobin values of fall chinook salmon cultured for 4 weeks at four water temperatures. Average weights of the fish were 3.2 to 4.0 g (from Banks et al. 1971).

Rearing temperatures (°C)	Number of fish	Hematocrit (%)		Hemoglobin (g/100 ml blood)	
		$\bar{X}$	Range	$\bar{X}$	Range
10.0	10	32.2	29-36	5.4	4.5-6.3
12.7	10	35.8	31-40	5.4	4.8-6.4
15.6	10	37.6	32-43	5.9	4.9-6.8
18.3	10	38.9	35-46	6.4	5.4-7.3

Profiles of mean hematocrit and hemoglobin values are compared to a profile of the water temperatures (Figure 26). Note that there was a general decline of both hematocrits and hemoglobins throughout the spring of 1980. This is the same pattern noted in Dworshak steelhead (Table 3), but opposite to that of the Tucannon steelhead (Table 13). Negative correlations of hematocrits and hemoglobins to water temperature were as highly significant for Leavenworth spring chinook salmon as positive correlations in smaller fall chinook salmon found by Banks et al. (1971) cultured under controlled temperature conditions (Figures 27 and 28). Although hematocrit values, gill Na^+-K^+ ATPase, and fork lengths frequently could not be correlated on any specific sampling period, there were significant correlations between mean values for each period throughout the season (Table 24). However, these may still be coincidental seasonal adjustments of populations, and mean fork length, hematocrit, and Na^+-K^+ ATPase may not be directly dependent upon each other.

Correlations between individual hematocrit and hemoglobin values were highly significant in Leavenworth NFH spring chinook salmon in both winter and spring (Table 24). This correlation was also highly significant for the mean hematocrit and hemoglobin values (Figure 29). Data indicate that hematocrit data alone could be used to accurately predict hemoglobin values for large sample sizes.

Mean cell hemoglobin concentrations (MCHC) of Leavenworth NFH spring chinook salmon peaked in late March, and were at a low level throughout April, a probable indication that the fish were not stressed at the time of release (Table 22). Average MCHC values could not be correlated with other stress or smolting indicators.

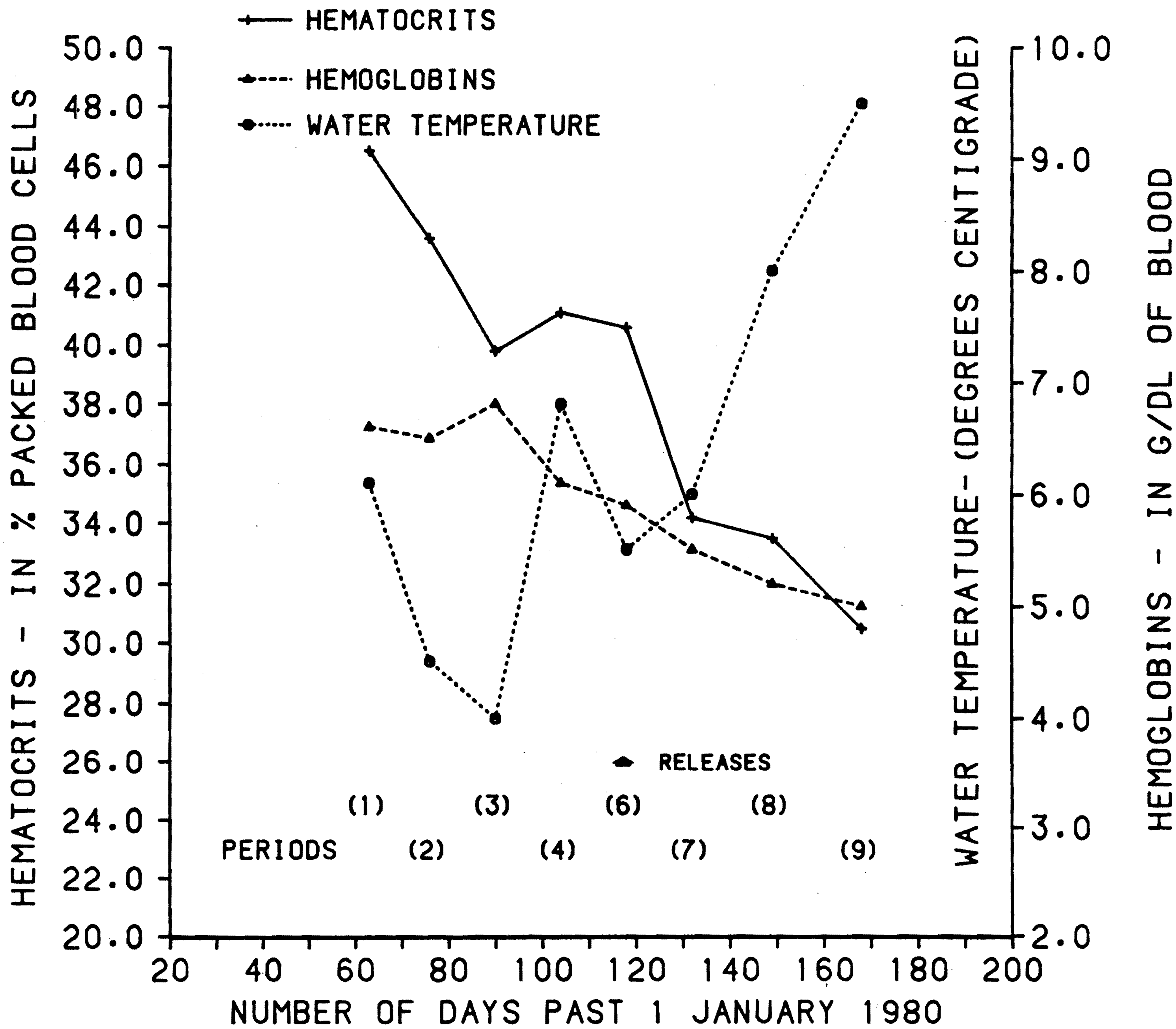


Figure 26.--Average hematocrit and hemoglobin values and raceway water temperatures for Leavenworth NFH spring chinook salmon during spring 1980.

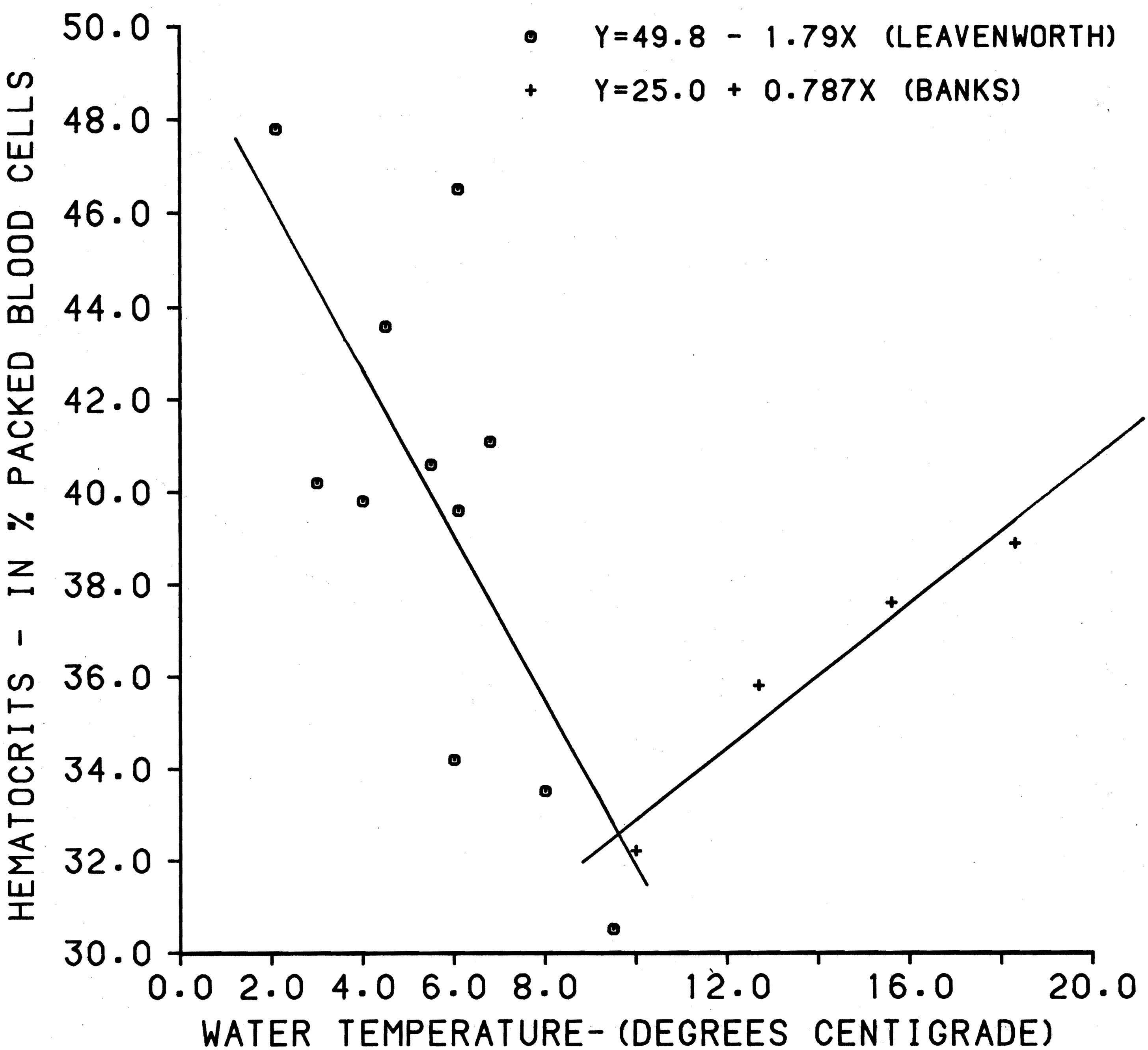


Figure 27.--A comparison of the regressions of mean hematocrit values of Leavenworth NFH spring chinook salmon on Leavenworth NFH water temperatures during spring 1980, and regression of mean hematocrit values of fall chinook salmon cultured at different water temperatures by Banks et al. (1971). r = 0.720 ($P < 0.02$) Leavenworth NFH spring chinook salmon, 1980. r = 0.971 ($P < 0.05$) Banks et al. (1971) fall chinook salmon.

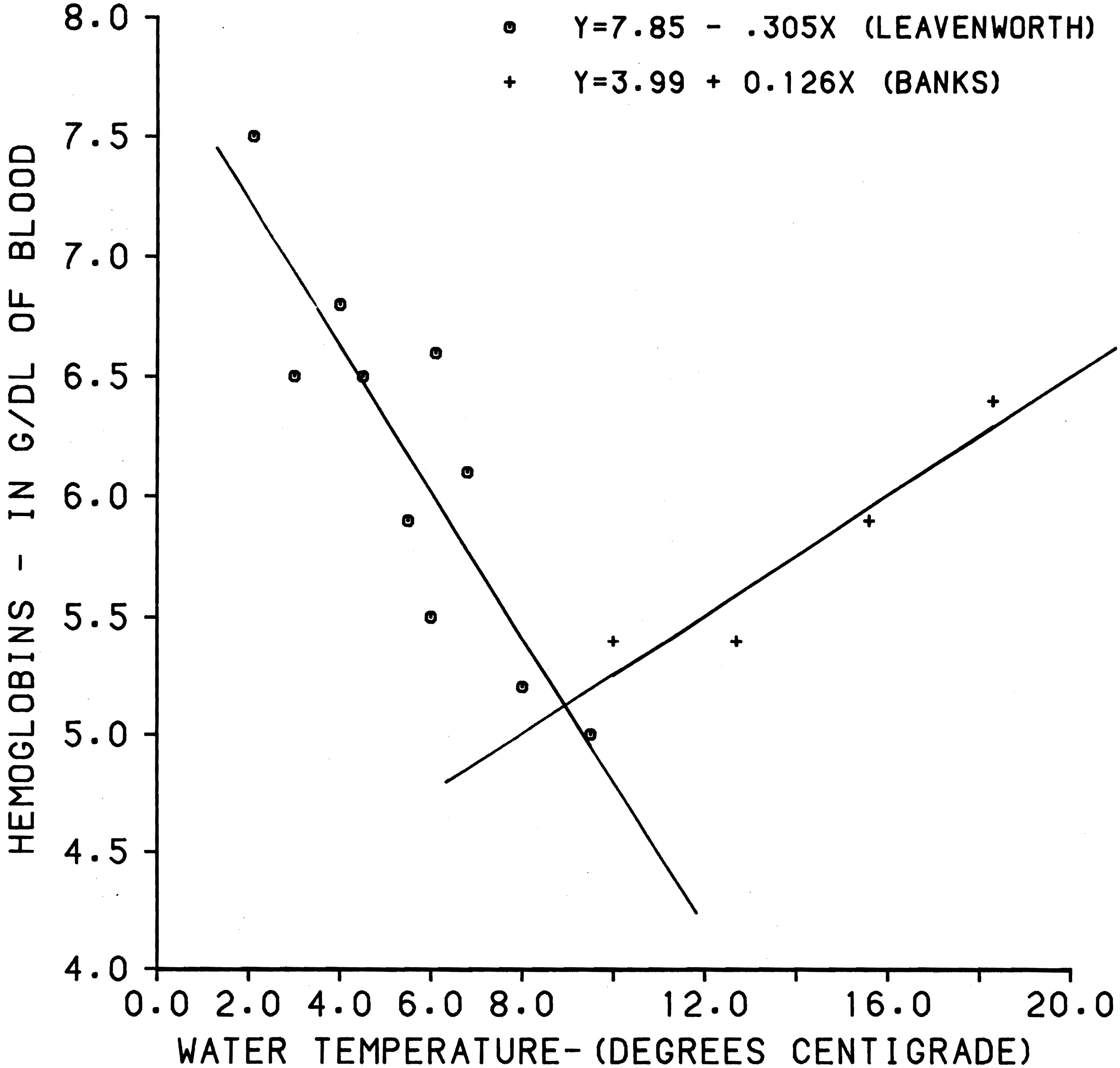


Figure 28.--A comparison of the regressions of mean hemoglobin values of Leavenworth NFH spring chinook salmon on Leavenworth NFH water temperatures during spring 1980, and regression of mean hemoglobin values of fall chinook salmon cultured at different water temperatures by Banks et al. (1971). r = 0.885 ($P < 0.001$) Leavenworth NFH spring chinook salmon, 1980. r = 0.946 ($P < 0.10$) Banks et al. (1971) fall chinook salmon.

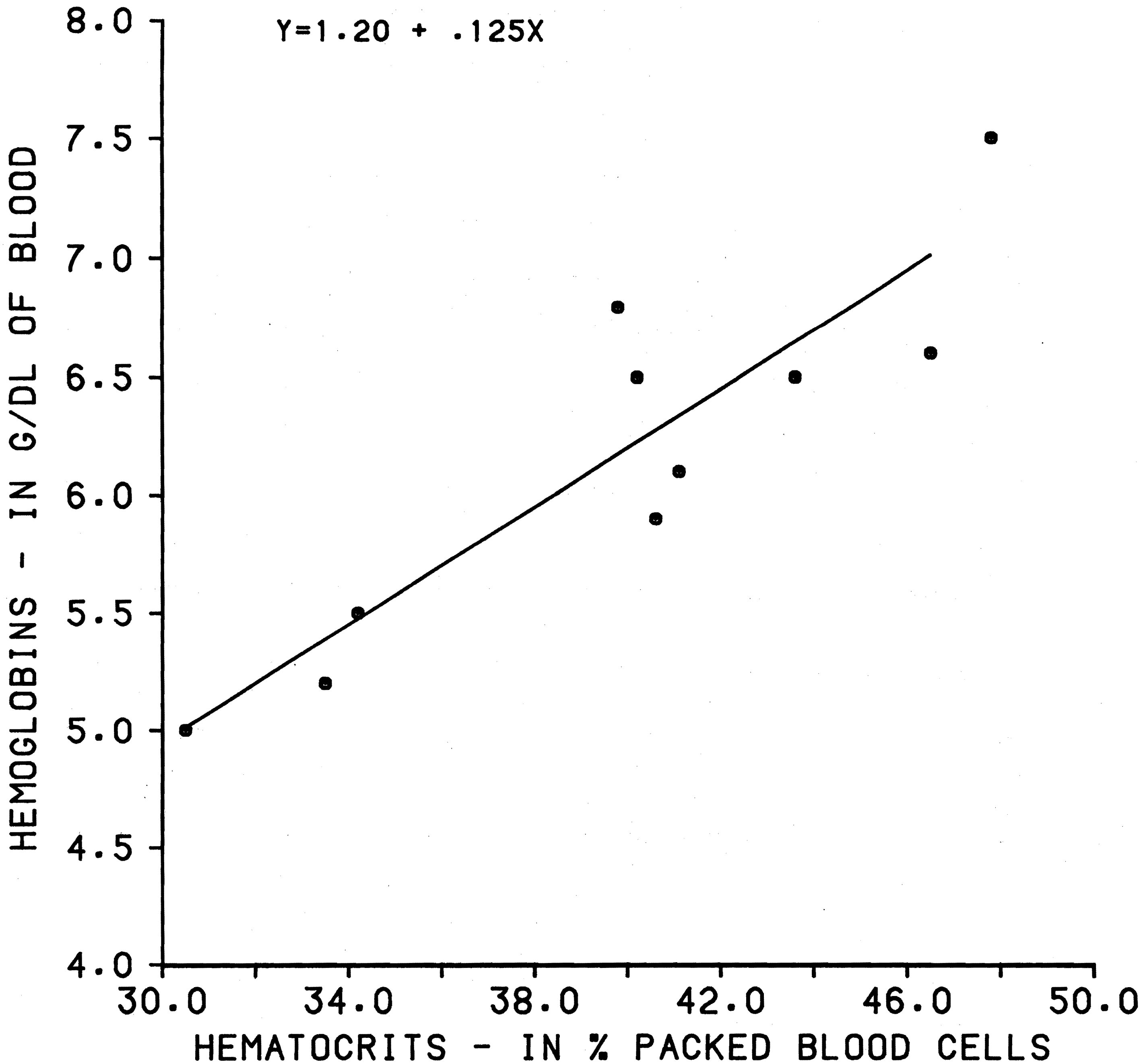


Figure 29.--Regression of average hemoglobin values on average hematocrit values of the Leavenworth NFH spring chinook salmon during spring 1980. $r = 0.903$; $P < 0.001$.

IFAT-BKD

Specimens of Leavenworth NFH spring chinook salmon from the first, third, and sixth sampling periods of 1980 were examined for the presence of BKD organisms by the Indirect Fluorescent Antibody Test (IFAT).

The data in Table 29 indicate a major increase (from 2 to 80%) in the percentage of samples positive for BKD in March followed by a decrease just after release in late April. Although the incidence of BKD was high, the intensity of infection ranged from very light to light, and it appears that BKD is not a serious threat to this stock. Our field notes indicate that of approximately 700 fish that were examined internally at Leavenworth NFH in late 1979 and early 1980, only 10 (approximately 1.4%) had BKD type lesions visible to the naked eye. We did note that 6.7% of the fall-marked fish sampled on 23 April (release) had BKD type lesions in the kidneys.

Table 29.--Incidence of BKD organisms and relative intensity in the kidneys of Leavenworth Hatchery spring chinook salmon sampled in 1980.

		% of samples positive for BKD				Range of intensity (no. of organisms/150 microscopic fields)
Period	Date	Anterior	Posterior	Both	Total	
1	3 March	1.7	0	0	1.7	4
3	31 March	53.3	61.7	35.0	80.0	1 to 34
6	28 April	28.6	53.6	17.9	66.1	1 to 16

Histopathology

A detailed summary of the pathological conditions is presented in Table 30. For comparative purposes, these data are further summarized with data from other hatcheries in Table 9.

Table 30.--Pathological conditions observed in Leavenworth Hatchery spring chinook salmon in 1980 and their percentage of incidence.[a/]

Organ and pathology	Incidence (%)											
	Period 1 (severity)[b/]				Period 3 (severity)				Period 6 (severity)			
	I	II	III	Total	I	II	III	Total	I	II	III	Total
Eye												
skeletal muscle lesions	32.2	0	0	32.2	36.7	0	0	36.7	38.3	0	0	38.3
retobulbar granulomatous inflammation	0	0	0	0	0	0	0	0	0	0	1.7	1.7
Gills												
increased numbers of lympocytes	74.5	27.1	0	100.0	81.7	16.7	0	98.3	48.3	20.0	1.7	70.0
epithelial cell formation	13.6	18.6	1.7	33.8	28.3	70.0	1.7	98.3	65.0	8.3	0	73.3
lymphatic telangiectasis of secondary lamellae	25.4	32.2	6.8	64.4	0	0	0	0	0	0	0	0
vascular telangiectasis of secondary lammelae	0	0	0	0	0	0	0	0	1.7	0	0	1.7
Olfactory sac												
focal mononuclear cell infiltration	88.1	6.8	0	94.9	80.0	11.7	0	91.7	38.3	10.0	0	48.3
acute focal hemmorhage	0	0	0	0	0	0	0	0	1.7	0	0	1.7

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

At or near release, Leavenworth NFH spring chinook salmon were characterized by marked decreases in pathological conditions of gill and olfactory sac tissues (Table 30). Types and severity of lesions encountered were low, and no evidence of parasitic activity was found in either the gills or olfactory sac.

In addition to microscopic examination of tissue by the veterinary pathologist, we made notes in the field of any macroscopic lesions observed in the various organs from the 700 or more fish examined. One precocious male was noted, and it showed symptoms of nephrocalcinosis; eight fish were noted to have clinical symptoms of BKD (exophthalmos, kidney lesions); one lesion of the spleen; one lesion of the liver; two fish with ascites, and one with lesions of the posterior air bladder. This is roughly 2% of the total samples examined.

Summary

Serial sampling of Leavenworth NFH spring chinook salmon in late 1979 and early 1980 indicated that general fish health was excellent, and may have actually improved (over March) by the time of release in late April. Water temperatures at this time had declined temporarily (Figure 20), which would have reduced handling stresses. A comparison of gill Na^+-K^+ ATPase curves between 1980 and two other years indicated that a typical pattern developed, and the bulk of the fish were released on an actively rising profile (Figure 21). Comparisons made at the time of release demonstrated that mean hematocrits were significantly lower in the fall mark group and channel control groups than in fish from Pond 17, and that mean gill Na^+-K^+ ATPase values were significantly higher for all other release groups tested when compared to Pond 17, the normal groups (Table

23). Since Pond 17 fish were used to determine the seasonal Na^+-K^+ ATPase profile, the conclusion is that all test groups were at or rapidly approaching peak Na^+-K^+ ATPase levels. Significant correlations between gill Na^+-K^+ ATPase and mean fork lengths enabled us to estimate that at least 40 to 50% of the samples were probably smolting during the release period. Smolting activity probably continued at a high rate in the released fish. A peak Na^+-K^+ ATPase activity coincided with rapidly declining plasma Cl^- and mean hematocrit values after 28 April and increasing plasma K^+ and MCHC in fish held after release (Table 22). These events also coincided with a sharp increase in water temperature. Although holding the fish slightly longer might have produced more smolts, it might have been with some risk as indicated by increased stress indicator values (K^+, MCHC).

Histopathology and BKD analyses indicate that the incidence of combined lesions of any importance with severities that would call for a pessimistic prognosis are probably less than 10%. Reduced incidences of lesions to the eyes and olfactory sacs and the absence of parasites at the time of release were also noted.

Carson National Fish Hatchery

General

We sampled spring chinook salmon from a fall marking test at Carson NFH in late 1979 (Table 31), then collected full data from March until the fish were released between 12 and 15 May 1980. During the sampling time, the fish were cultured in well water at temperatures of 6° to 7°C (Table 31). No fish were held over for post-release sampling.

Sampling period days are presented with 1 January 1980 as Day +1 and 31 December as Day -1 to simplify computer programming and are presented in Table 31 with the calendar dates for each sampling period.

The fork lengths of the fish used in the sampling surveys averaged 132 mm in 1978, 127 mm in 1979, and 117 mm in 1980 at the times of release in early May.

Gill Na^+-K^+ ATPase

The gill Na^+-K^+ ATPase profile in 1980 was characterized by a gradual increase between the first two periods, followed by a sharp increase in early April, and probably near maximal activity at the time of release (Figure 30). Na^+-K^+ ATPase activities were not followed beyond release, but comparison with the profiles collected in 1978, 1979, and 1980 (Figure 30) suggests that enzyme performance was spatially and quantitatively repeatable, which substantiates the probability that in 1980 maximum activity was reached.

There were no significant correlations between gill Na^+-K^+ ATPase values in any one period and the average fork lengths of fish used for the pooled gill samples. In the first period there was negative correlation ($r = 0.814$; $P < 0.002$) between gill Na^+-K^+ ATPase and plasma K^+; and

Table 31.--Summary data for spring chinook salmon samples collected at Carson National Hatchery in late 1979 and in the spring of 1980, with means, standard deviations ( ), and ranges. Sample size = 60, released 12 May 80.

	Period				
Item	A	1	2	3	4
Date	13 Dec 79	4 Mar 80	4 Apr 80	17 Apr 80	12 May 80
Days>Jal[a]	-19	64	94	107	132
Temp.°C[b]	6.7	6.7	6.7	6.7	6.7
Avg. Fk Ln[c]	93.4	102.6	109.5	112.5	116.7
	(5.7)	(6.9)	(7.4)	(8.2)	(9.5)
(Range)	79-112	93-130	90-126	98-137	90-135
Avg. ATP FK Ln[d]	---	103.8	110.4	112.0	116.4
	---	(4.6)	(7.2)	(7.8)	(10.1)
(Range)	---	99-130	96-122	100-130	98-135
Avg. ATP[e]	---	9.5	12.5	18.6	20.4
	---	(1.7)	(2.5)	(3.0)	(4.1)
(Range)	---	6.7-11.7	8.4-16.0	14.3-24.2	13.3-27.6
Avg. Hct[f]	36.4	38.8	47.3	53.3	56.7
	(4.7)	(4.1)	(4.9)	(6.4)	(8.9)
(Range)	26-48	28-48	32-55	30-65	30-72
Avg. Hb[g]	6.5	---	6.5	7.2	8.2
	(1.0)	---	(1.1)	(1.4)	(1.6)
(Range)	4.3-8.7	---	3.6-8.8	2.7-12.5	2.4-10.6
Avg. MCHC[h]	17.9	---	14.1	13.5	14.4
	(2.3)	---	(3.1)	(1.9)	(2.0)
(Range)	11.6-23.1	---	7.2-26.2	9.0-23.1	8.0-21.2
Avg. Na$^+$[i]	---	180.4	144.6	151.5	143.7
	---	(17.4)	(7.1)	(7.8)	(23.1)
(Range)	---	160-255	130-154	141-167	89-200
Avg. K$^+$[j]	---	2.16	1.03	2.32	1.86
	---	(0.94)	(0.60)	(1.00)	(1.40)
	---	1.05-4.60	0.55-3.35	0.82-3.98	0.57-6.80
Avg. Cl$^-$[k]	---	132.3	136.7	128.6	109.5
	---	(9.1)	(10.2)	(12.0)	---
(Range)	---	103-145	118-154	111-147	109-110(n=2)
Na$^+$/Cl$^-$[l]	---	1.38	1.07	1.18	---
	---	(0.19)	(0.09)	(0.10)	---
(Range)	---	1.17-2.07	0.94-1.26	1.02-1.34	---

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average for lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. ATP: The average gill ATPase levels for that period. (Na$^+$-K$^+$ activity in μ moles Pi/mg protein/hour.
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na$^+$: The average plasma sodium for that period (in meq/l).
j/ Avg. K$^+$: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl$^-$: The average plasma chloride for that period (in meq/l).
l/ Na$^+$/Cl$^-$: The ratio of the plasma sodium to chlorides for that period, averaged.

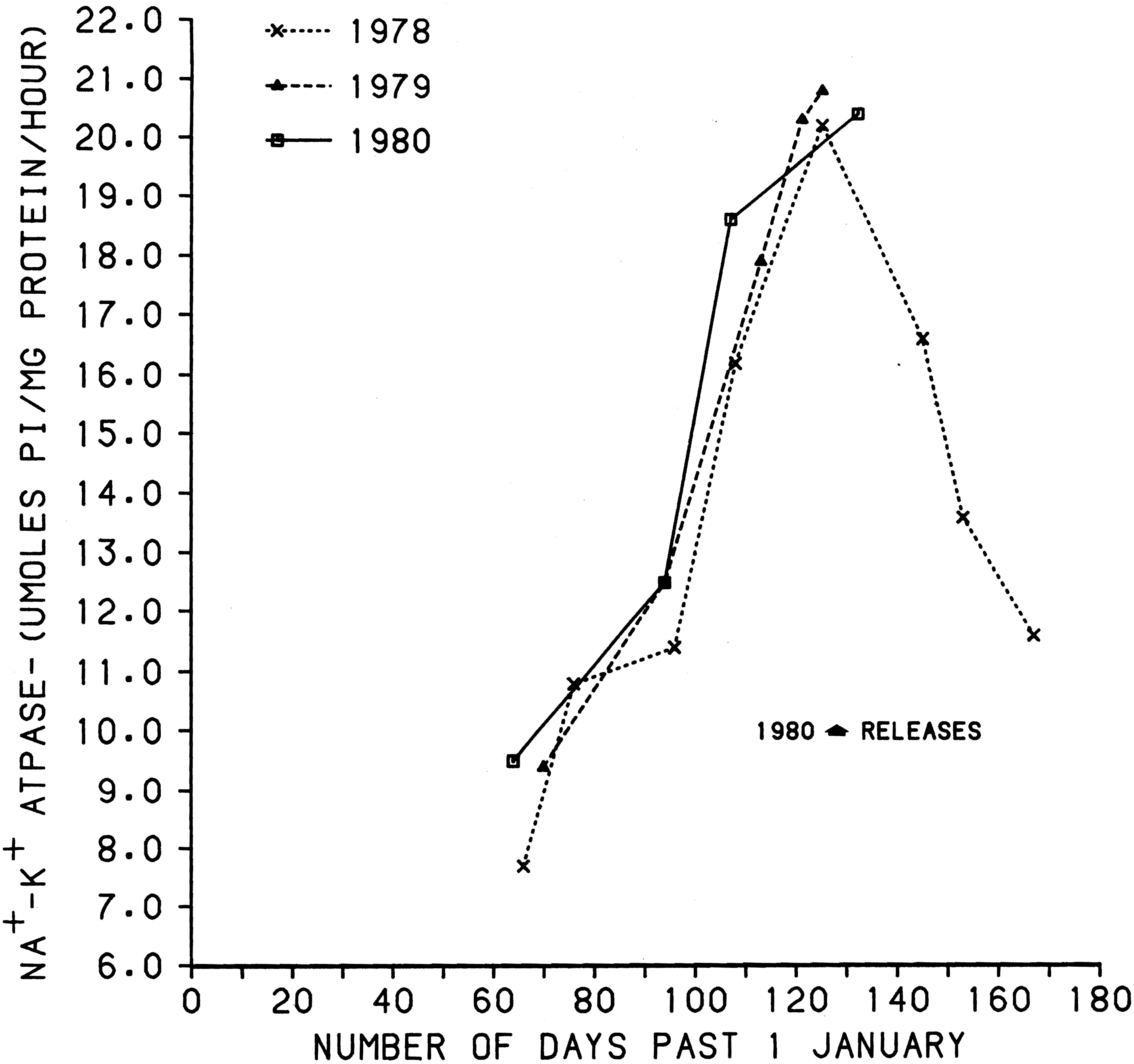


Figure 30.--Average gill Na^{+}-K^{+} ATPase values for Carson NFH spring chinook salmon during 1978, 1979, and 1980.

in the third period there was a positive correlation between gill Na^+-K^+ ATPase and plasma Cl^- ($r = 0.685$; $P < 0.05$). In the fourth period (at release), there was a positive correlation between gill Na^+-K^+ ATPase and hematocrit values ($r = 0.646$; $P < 0.05$). However, there was no consistency in any of these correlations between periods.

Trends of mean data for the entire sampling period were different. Mean fork lengths, gill Na^+-K^+ ATPase values, hematocrits, and hemoglobins all increased almost linearly throughout the sampling season (Figure 31), and there was a positive correlation between mean gill Na^+-K^+ ATPase and mean hematocrit values ($r = 0.975$; $P < 0.05$). As mean gill Na^+-K^+ ATPase values increased, mean plasma Na^+ and Cl^- values decreased (Table 31). However, there were no significant negative correlations between mean gill Na^+-K^+ ATPase values and plasma electrolytes.

At release, the mean gill Na^+-K^+ ATPase activity was much higher for spring chinook salmon from Carson NFH (20.4) than those from Leavenworth NFH (12.5), and the rate of increase in activity during the month of April was greater for the Carson NFH fish. The percentage of Carson NFH fish with gill Na^+-K^+ ATPase values $\geq$ 20 went from 40% in the third period (17 April) to 60% in the fourth (12 May), indicating that most of the rise in gill Na^+-K^+ ATPase had taken place (the highest value in the second period, 4 April, was 16.0). Year to year consistency of the profiles (possibly influenced by constant water temperature) plus this quantitative index indicate that at least 50% of the fish were smolting at the time of release.

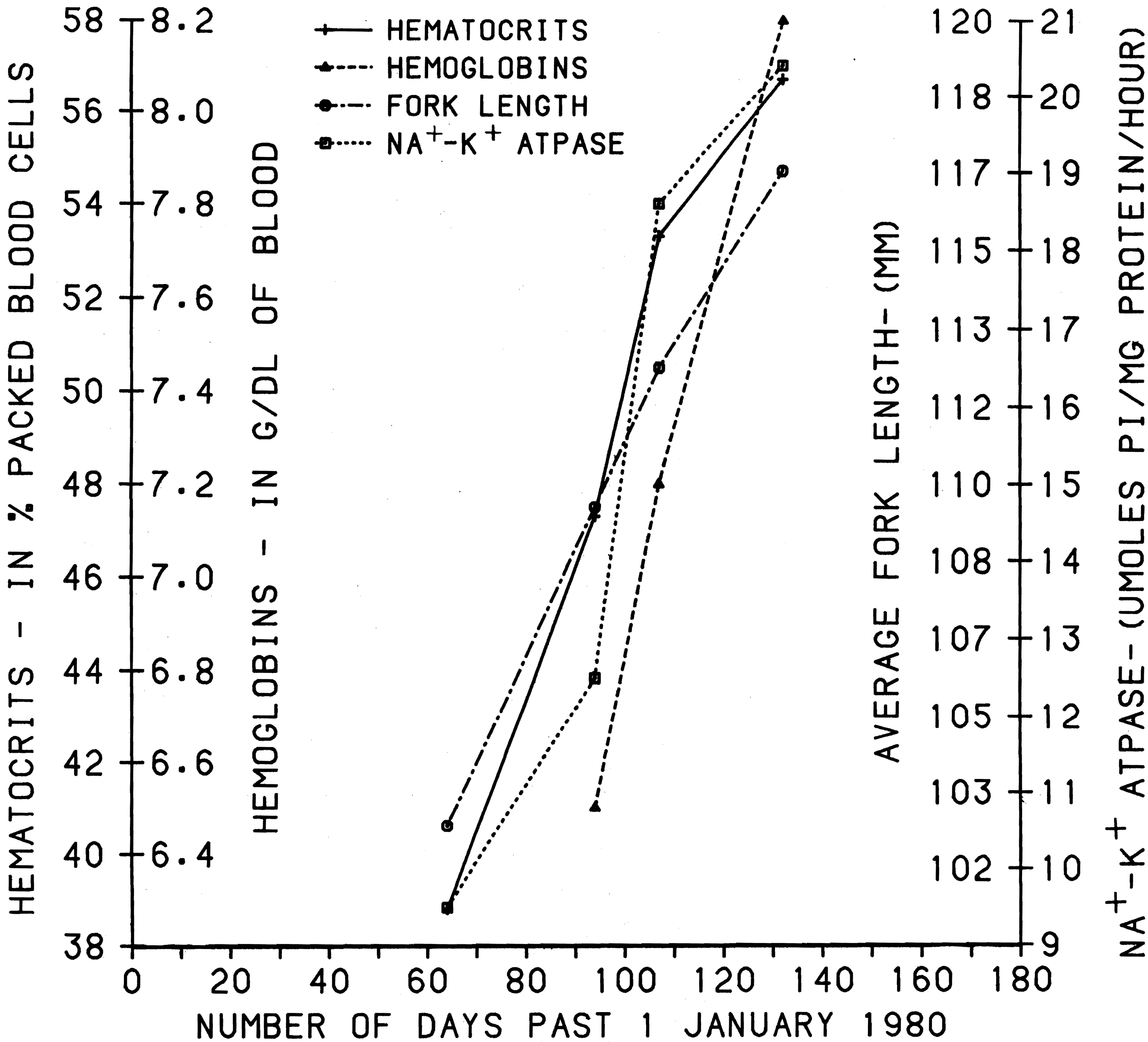


Figure 31.--Average fork lengths, gill Na^+-K^+ ATPase values, hematocrits, and hemoglobins of the Carson NFH spring chinook salmon during spring 1980.

Plasma Electrolytes

Mean plasma electrolyte values (Table 31) were within expected ranges at the time of release (Table 25). Plasma Na^+ was characterized by higher than expected values in early March followed by a sharp decline and leveling off in the expected range near release (Table 31). Plasma Cl^- values declined to their lowest level at the time of release, which coincided with the peak gill Na^+-K^+ ATPase values (Table 31). This further corroborates evidence of good smolting activity at release.

The stress indicators, plasma K^+ and the MCHC, did not show sharp increases at release, and mean values were within normal ranges (Table 31). Comparison of plasma K^+ profiles between Carson and Leavenworth NFH spring chinook salmon shows a similarity in relative changes and timing (Figure 32), and suggests that holding the Carson fish beyond the proposed release dates might have induced a post-smolt stress.

Table 32.--Hematocrit and hemoglobin values for Carson Hatchery spring chinook salmon at the time of release: 1978-1980.

	Hematocrits		Hemoglobins	
Year	Mean	S.D.	Mean	S.D.
1978	44.6	± 11.9	6.9	± 1.6
1979	36.1	± 10.1	5.2	± 1.8
1980	56.7	± 8.9	8.2	± 1.6

Hematology

Mean hematocrit and hemoglobin values of Carson NFH spring chinook salmon were much higher at the time of release in 1980 than in previous years, and were the highest encountered in chinook salmon thus far (Tables 31 and 32).

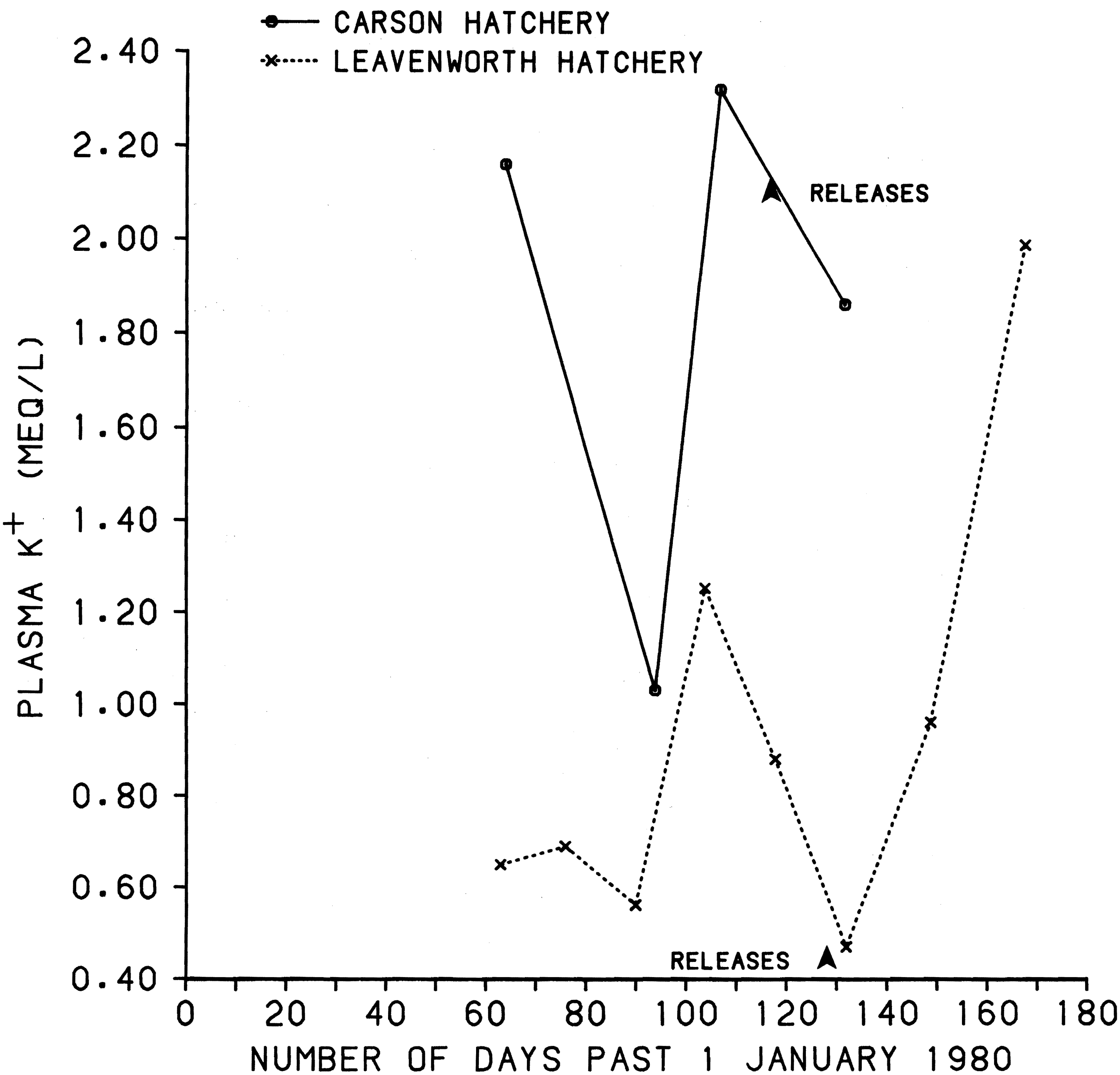


Figure 32.--Average plasma K^+ values for Carson and Leavenworth NFH spring chinook salmon during spring 1980.

Seasonal mean hematocrit and hemoglobin values of the Carson NFH fish (Table 31) are almost the reverse of those from Leavenworth NFH (Table 22). Not only was the trend in Carson NFH fish one of steady increases, starting from a low in December 1979 (Table 31), but all of the values exceeded those of 1978 and 1979 as early as April. There were positive correlations between mean fork lengths and mean hematocrits ($r = 0.993$; $P < 0.05$), mean fork lengths and mean hemoglobins ($r = 1.000$; $P < 0.05$), and mean gill Na^+-K^+ ATPase and mean hematocrits ($r = 0.975$; $P < 0.05$). Note that there were no individual hematocrit values below 30% at the time of release.

These data are also unique in that they represent major changes in hematology in a stable water temperature. Unfortunately, 1980 profiles were not continued for post-release fish, as the significant correlations of means for lengths, hematocrits, and gill Na^+-K^+ ATPase values may prove to be of value for this stock of fish in future years. In Figure 33, we show that the mean gill Na^+-K^+ ATPase could be predicted from the mean hematocrits (in 1980). Since the average growth would (presumably) continue an upward trend even for post-smolt fish, if the mean Na^+-K^+ ATPase and hematocrit value declined after smolting, it might be possible to predict smolting (in this stock) from profiles of mean hematocrit data.

IFAT-BKD

Specimens of Carson NFH spring chinook salmon from the first, second, and fourth sampling periods of 1980 were examined for the presence of BKD organisms by IFAT.

At release, the percentage of fish in the sample population with identified BKD organisms was between that of 1978 and 1979 (Table 33).

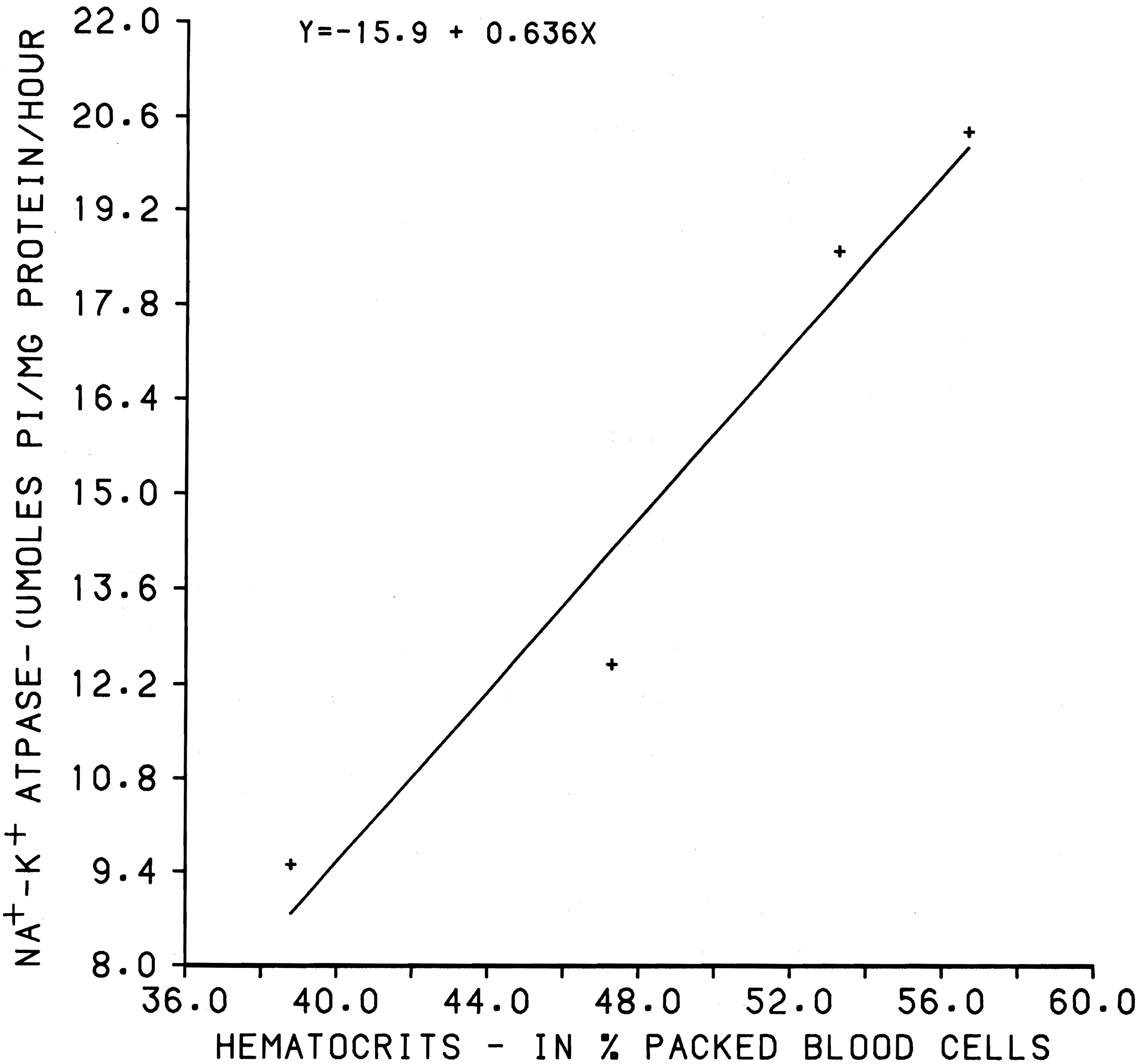


Figure 33.--Regression of the mean gill Na^{+}-K^{+} ATPase values on mean hematocrits of Carson NFH spring chinook salmon during spring 1980. $r = 0.976$; $P < 0.05$.

Table 33.--The indicence of BKD organisms in juvenile Carson Hatchery spring chinook salmon from 1978-80 as determined by IFAT.

Date	% of fish with BKD bacteria in the kidneys Anterior kidney	Posterior kidney	Both kidneys	Total
1978 (at release)	--	--	--	50.8 (light to moderate)
1979 (at release)	--	--	--	33.3a/
1980				
3 March	5.0	5.0	0	10.0 (light)
4 April	8.3	1.7	0	10.0 (light)
12 May (release)	6.3	6.3	26.6	31.9b/

a/ 25% of the infected fish were classed as "severe" in 1979.

b/ Only 4% of the infected fish were classed as "severe" in 1980.

However, note that there were six times as many fish in 1979 with class III (severe) infections as in 1980. The significance of this is confirmed by the excellent hematological record in 1980 fish.

After release in 1980, IFAT-BKD tests were conducted on an additional 25 Carson NFH fish to determine if BKD could possibly affect the sensory organs. We compared tissue smears of anterior and posterior kidney, hind gut, brain, behind (and within) the eye, and the olfactory nare and found that 3 out of 25 (12%) had BKD organisms in posterior kidney ranging from 3 to 35 organisms/150 microscopic fields (m.f.), and 10 out of 25 (40%) had BKD organisms in the olfactory nare ranging from 1 to 420/150 m.f.

Histopathology

A summary of the pathological conditions observed is presented in Table 34. For comparative purposes, these data are further summarized with data from the other hatcheries in Table 9. The main characteristics of this histopathological profile of the Carson NFH were a decrease in lesions of the eyes and increases in gill lesions. There was a pronounced decrease in gill lesions of intermediate (class II) severity from the earliest part of the season, which may have resulted from early disease treatment. Lesions of the olfactory nares were consistently high throughout the four sampling periods and were almost four times the rate of 1979 (Novotny and Zaugg 1981) and almost double the rate of Leavenworth NFH spring chinook salmon. Although the pathologist's report for the 1979 studies (Novotny and Zaugg 1981) and our IFAT-BKD studies in 1980 suggest that BKD organisms may be associated with olfactory sac pathology, we have not completely confirmed this.

Table 34.--Pathological conditons observed in 1980 Carson Hatchery spring chinook salmon and their percentage of incidence.[a]

Organ and pathology	Incidence (%) Period 1 (severity)[b] I	II	III	Total	Period 2 (severity) I	II	III	Total	Period 3 (severity) I	II	III	Total	Period 4 (severity) I	II	III	Total
Eye																
Skeletal muscle lesions	82.8	0	0	82.8	41.7	0	0	41.7	60.0	0	0	60.0	41.7	0	0	41.7
Retrobulbar fat lesions	0	0	0	0	0	0	0	0	1.7	0	0	1.7	1.7	0	0	1.7
Acute focal hemmorhage	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	1.7
Retrobulbar granulomatous inflammation	0	0	0	0	0	0	0	0	1.7	0	0	1.7	0	0	0	0
Retrobulbar pyogranulomatous inflammation	0	0	0	0	0	0	0	0	0	1.7	0	1.7	0	1.7	1.7	3.4
Gills																
Increased numbers of lymphocytes	43.1	52.2	0	98.2	63.3	11.7	0	75.0	53.3	18.3	0	71.7	78.3	15.0	0	93.3
Epithelial cell formation	65.5	31.0	0	96.6	53.3	6.7	0	60.0	23.3	1.7	0	25.0	46.7	6.7	0	53.3
Vascular telangiectasis of secondary lamellae	5.2	0	0	5.2	8.3	0	0	8.3	3.3	0	0	3.3	0	0	0	0
Ciliated protozoan parasite	0	0	0	0	0	0	0	0	1.7	0	0	1.7	0	0	0	0
Olfactory sac																
Focal mononuclear cell infiltration	89.7	5.2	0	94.8	85.0	5.0	0	90.0	75.0	10.0	0	85.0	93.3	5.0	0	98.3
Pyogranulomatous inflammation	3.4	1.7	0	5.2	0	1.7	0	1.7	1.7	0	3.3	5.0	1.7	1.7	1.7	5.1

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

Summary

Serial sampling of 1978 brood Carson NFH spring chinook salmon in late 1979 and early 1980 indicated that general health of these fish was good, and that at release, there was clinical evidence of improvements over the fish released in 1979. Gill Na^{+}-K^{+} ATPase profiles have been consistent in timing and level of activity for 3 years (Figure 30), and all of the evidence indicates that in 1980 the fish were released at maximum gill Na^{+}-K^{+} ATPase activity, and that at least 50% of the fish were smolting. The average size at release was the smallest of the 3 years.

In spite of a constant 6.6°C water temperature, mean hematocrits paralled mean gill Na^{+}-K^{+} ATPase values throughout the season. Statistically significant correlations suggest that mean hematocrit data may be a useful tool at this hatchery for predicting smoltification in spring chinook salmon, should this relationship prove consistent from year to year.

There were no low hematocrit or hemoglobin levels in the 1980 samples, and no incidence of severe (Class III) BKD. Means and ranges of the collected hematological data were above reported levels in some periods (Tables 28 and 31). An analysis of variance proved that there were highly significant differences in the mean hematocrits between periods ($F = 116$; $F_{0.0005,\ 4,240} = 5.20$).

Although histopathology data indicated increases in the incidences of eye and olfactory sac tissue lesions in 1980 as compared to 1979, there were no increases in severity. A separate IFAT-BKD test indicated that BKD organisms could be found in smears from the olfactory sacs of 10 out of 25 fish examined (40%).

Although we have presented an optimistic scenario for the Carson NFH spring chinook salmon released in 1980, one cautious comment must be made regarding the high hematocrits observed. In a general introductory statement, we pointed out that high hematocrits may be the result of dehydration. However, there is nothing in the literature to indicate what actual levels of hematocrit might be expected as indicators of the first stages of dehydration. Figure 34 clearly shows a major split in the hematocrit levels between winter and late spring. At the time of release, over 80% of the fish had hematocrits of 50% or more, and 30% of the fish had hematocrits of 60% or more.

As of now, we have no reasonable explanation for high hematocrits in the spring of 1980.

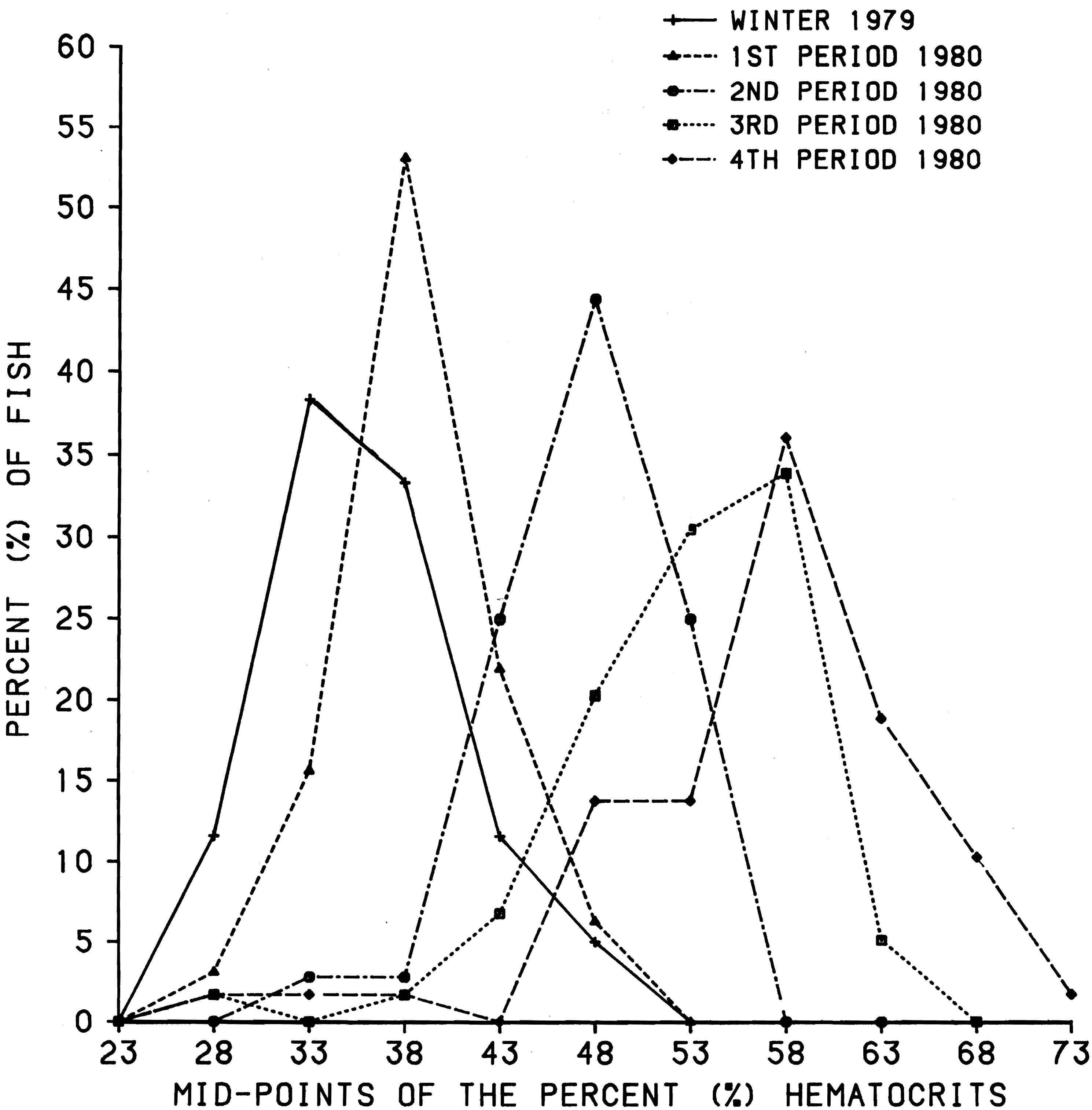


Figure 34.--Frequency of all measured hematocrits (expressed as % of fish) of Carson NFH spring chinook salmon released in 1980. Hematocrits were combined by units of 5 and are shown as the mid-points.

Kooskia National Fish Hatchery

General

Spring chinook salmon were sampled from Raceway 10 at Kooskia NFH in early March, and from Raceway 7 in April. Sampling continued beyond release (14-16 April) until early in June. Data are summarized and presented in Table 35, where periods 5, 6, and 7 represent post-release fish held over in Raceway 12.

Sampling periods are presented as days past 1 January 1980. Plasma electrolytes (Table 35) represent pooled data from 6, 3, or single fish, depending on fish size at the time of sampling.

Figure 35 shows water temperatures as measured in the raceways, and Table 35 shows average fork lengths of the Kooskia NFH fish sampled in 1980. The average size of fish taken at the time of release in 1978 (24 April) was 125 mm compared to 118 mm in 1980.

Gill Na^{+}-K^{+} ATPase

In 1980, the gill Na^{+}-K^{+} ATPase profile of Kooskia NFH fish was characterized by a rapid increase in mean values and standard deviations between 1 April and 15 May, followed by a very sharp decline (Figure 36). Peak Na^{+}-K^{+} ATPase activity obviously occurred 4 weeks after release. Mean Na^{+}-K^{+} ATPase activity at the time of release in 1978 (24 April) was 18.1; whereas in 1980 it did not reach this magnitude until approximately 7 May (Figure 36). Note that the maximum single gill Na^{+}-K^{+} ATPase value found at release was less than the lowest single gill Na^{+}-K^{+} ATPase value during the peak of activity (Table 35). Although there were significant positive correlations between fork lengths and gill Na^{+}-K^{+} ATPase activity during the third and fifth periods,

Table 35.--Summary data for spring chinook salmon samples collected at Kooskia National Hatchery in the spring of 1980, with means, standard deviations ( ), and ranges. Sample size = 60.

Item	Period						
	1	2	3	4	5	6	7
Date	5 March	19 March	2 April	16 April	30 April	14 May	5 June
Days>Jal[a]	65	78	92	106	120	134	155
Temp.-°C[b]	3.5	4.0	5.0	5.0	6.5	8.8	7.5
Avg. Fk Ln[c]	108.8	112.9	116.8	118.0	123.2	133.2	137.4
	(7.5)	(7.0)	(7.9)	(8.7)	(7.5)	(10.2)	(8.1)
(Range)	89-126	101-131	90-133	100-140	105-141	121-198	123-175
Avg. ATP Fk Ln[d]	108.5	113.5	115.7	117.2	122.9	132.8	137.1
	(3.0)	(6.7)	(5.7)	(7.1)	(5.5)	(6.2)	(5.5)
(Range)	104.0-112.7	104.3-124.3	106.3-122.3	105.7-130.0	112.7-130.3	125.3-141.0	125.0-144.0
Avg. ATP[e]	7.2	7.9	7.03	11.3	15.4	19.7	11.6
	(0.8)	(0.6)	(0.9)	(1.6)	(2.8)	(3.8)	(1.9)
(Range)	5.6-8.3	7.1-8.6	6.2-8.6	8.1-13.5	10.4-19.4	16.2-28.3	9.0-14.5
Avg. Hct[f]	42.4	43.6	40.0	45.2	48.5	47.4	37.8
	(4.2)	(4.5)	(6.5)	(6.0)	(8.5)	(8.6)	(5.9)
(Range)	33-57	30-56	18-53	32-57	27-63	20-61	22-48
Avg. Hb[g]	6.6	7.3	6.8	7.1	6.6	7.0	6.3
	(0.8)	(0.7)	(1.1)	(1.0)	(0.9)	(1.3)	(1.1)
(Range)	3.7-8.7	5.7-9.0	2.9-9.4	4.3-9.0	3.2-8.1	2.3-9.0	3.7-8.7
Avg. MCHC[h]	15.7	16.8	17.3	15.8	13.9	14.8	16.7
	(1.6)	(1.5)	(16.1)	(1.9)	(1.6)	(1.4)	(2.6)
(Range)	10.0-20.3	13.0-19.8	12.3-22.3	10.8-20.9	11.7-18.2	11.4-17.8	10.4-25.6
Avg. Na^+[i]	146.5	148.3	152.6	156.8	157.0	139.3	144.1
	(7.2)	(9.0)	(10.6)	(4.8)	(7.6)	(11.7)	(9.0)
(Range)	133.0-157.0	141-165	128-170	150-163	138-167	112-163	123-162
Avg. K^+[j]	0.65	1.18	0.62	1.53	0.70	0.81	1.26
	(0.26)	(0.78)	(0.36)	(0.72)	(0.31)	(0.50)	(1.11)
(Range)	0.32-1.18	0.44-2.65	0.32-1.46	0.58-2.60	0.31-1.27	0.26-1.82	0.24-6.1
Avg. Cl^-[k]	153.6	125.9	129.0	124.1	134.8	118.1	129.6
	(9.7)	(4.3)	(6.9)	(5.4)	(8.5)	(10.2)	(11.4)
(Range)	137-174	121-133	118-137	113-131	110-155	93-141	100-156
Na^+/Cl^-[l]	0.96	1.18	1.19	1.26	1.17	1.18	1.12
	(0.07)	(0.07)	(0.10)	(0.03)	(0.05)	(1.0)	(0.10)
(Range)	0.82-1.05	1.07-1.29	1.00-1.33	1.23-1.33	1.07-1.25	0.91-1.39	0.88-1.40

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μmoles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

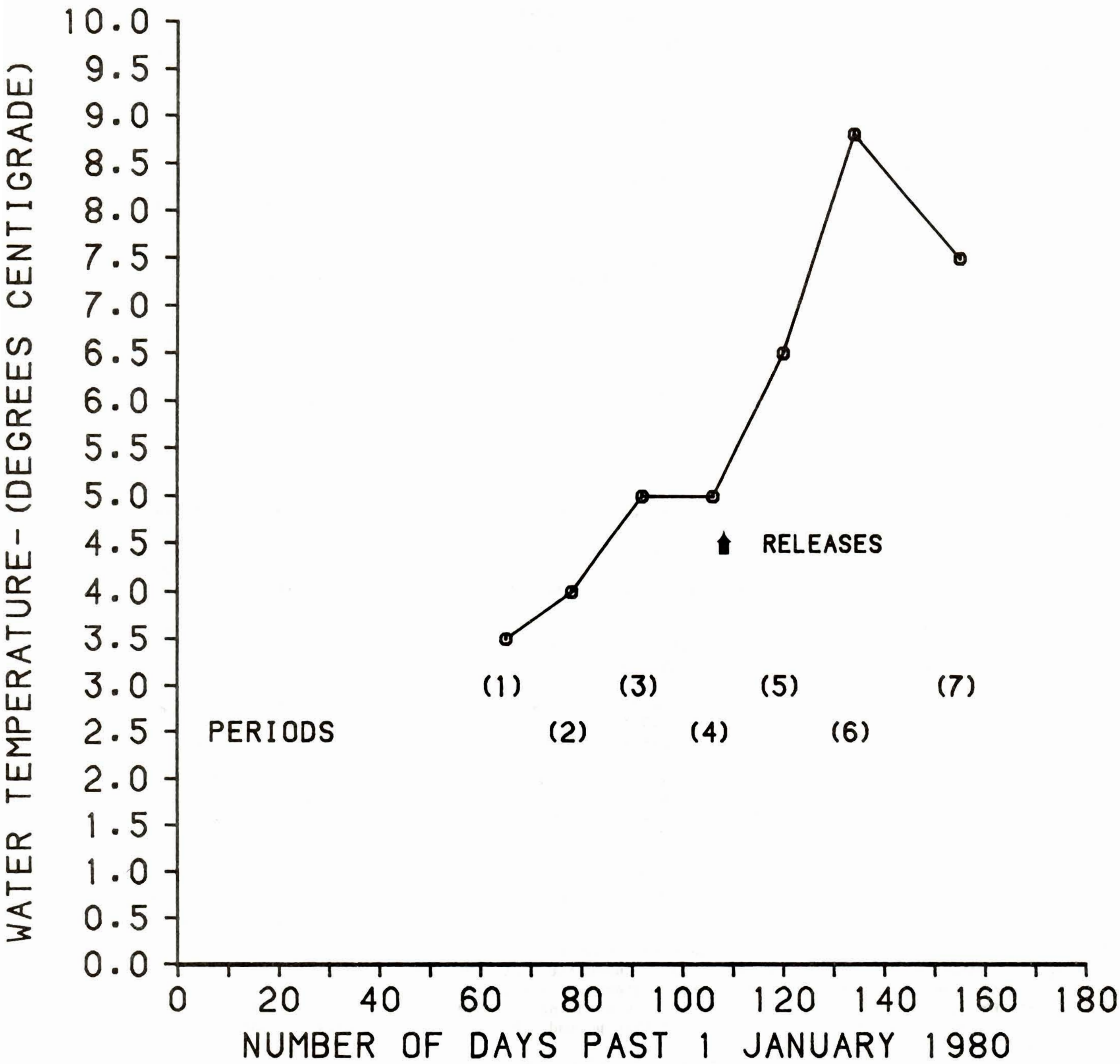


Figure 35.--Water temperatures measured in the raceways at Kooskia NFH during spring 1980.

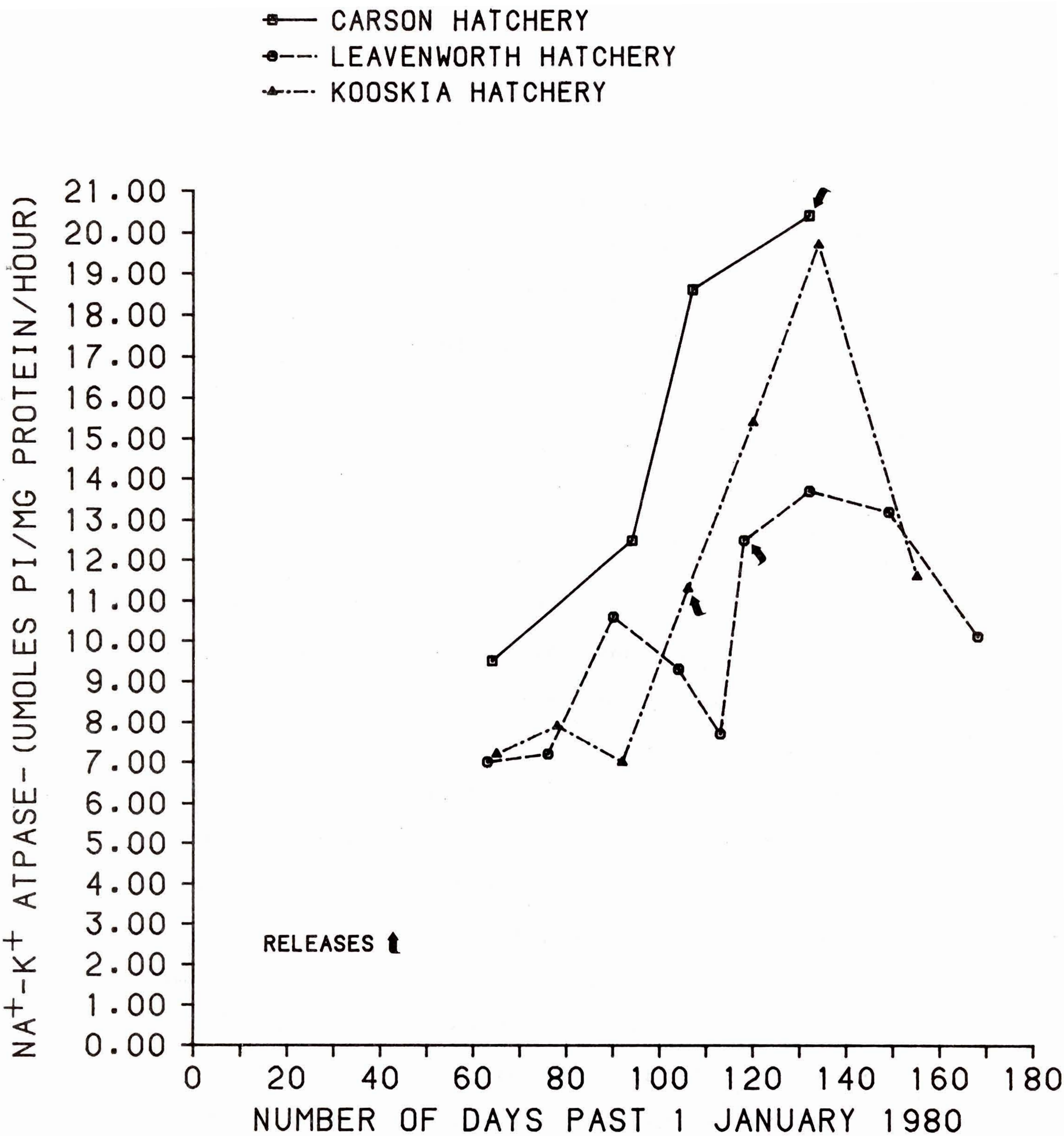


Figure 36.--Mean gill $Na^{+}-K^{+}$ ATPase values of Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

this was not the case at the time of release (fourth period). There was no correlation between mean fork lengths and mean gill Na^+-K^+ ATPase values. There was a significant positive correlation between mean gill Na^+-K^+ ATPase and the water temperature (Figure 37). However, this is probably coincidental, as the Na^+-K^+ ATPase profile normally includes a post-smolting decline, regardless of water temperature.

On the basis of the above information, especially with ranges of gill Na^+-K^+ ATPase values encountered, it appears that Kooskia NFH fish were still in a pre-smolting condition at the time of release.

Plasma Electrolytes

Mean plasma K^+ values (Table 35) were within expected ranges (Table 25), and the mean plasma Na^+ and Cl^- values were frequently at the upper end of the expected values. Mean Cl^- values in the first period were 14.6% higher than the highest mean Cl^- reported in Table 26. Mean plasma Na^+ and Cl^- values were much higher at the time of release in mid-April 1980 (Table 35). Both plasma Na^+ and Cl^- peaked on 30 April (5th period) and then declined rapidly to minimum levels at the same time gill Na^+-K^+ ATPase reached peak value (Table 35). Profiles of plasma Na^+ and Cl^- levels in Kooskia NFH spring chinook salmon were similar to those of Carson and Leavenworth NFH fish (Figures 38 and 39).

Profiles of stress indicators plasma K^+ and the MCHC, indicated minimals 2 weeks after release (Figure 40). A comparison of the profiles of mean plasma K^+ and MCHC values for spring chinook salmon from Carson, Leavenworth, and Kooskia NFH indicates distinct similarities, and that the spring low points of both indicators occurred about the first week in May (Figures 41 and 42). These data also suggest that Kooskia NFH fish may have been released too soon.

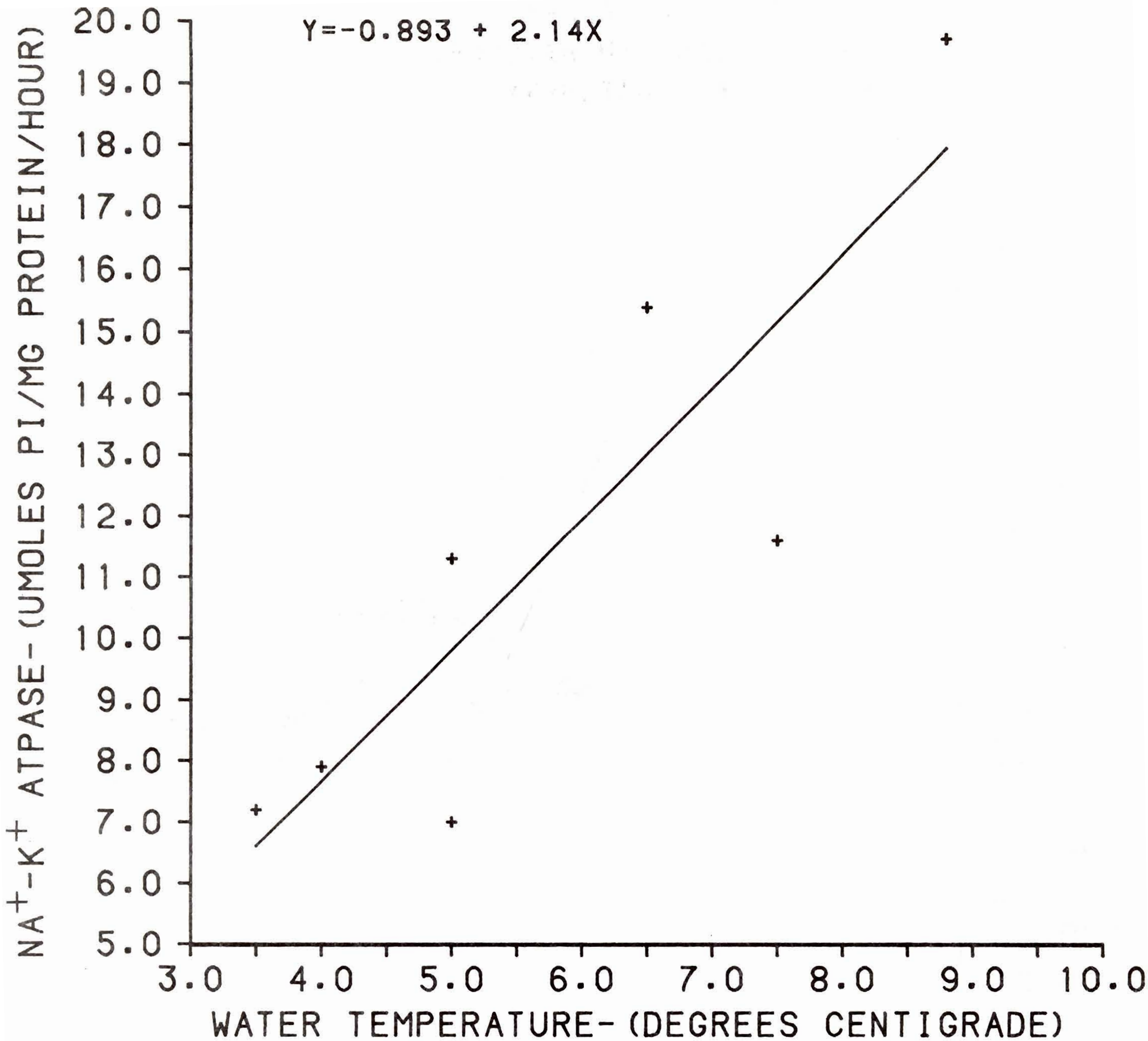


Figure 37.--Regression of average gill Na^{+}-K^{+} ATPase values of the Kooskia NFH spring chinook salmon on water temperature during spring 1980. $r = 0.873$ ($P = 0.02$).

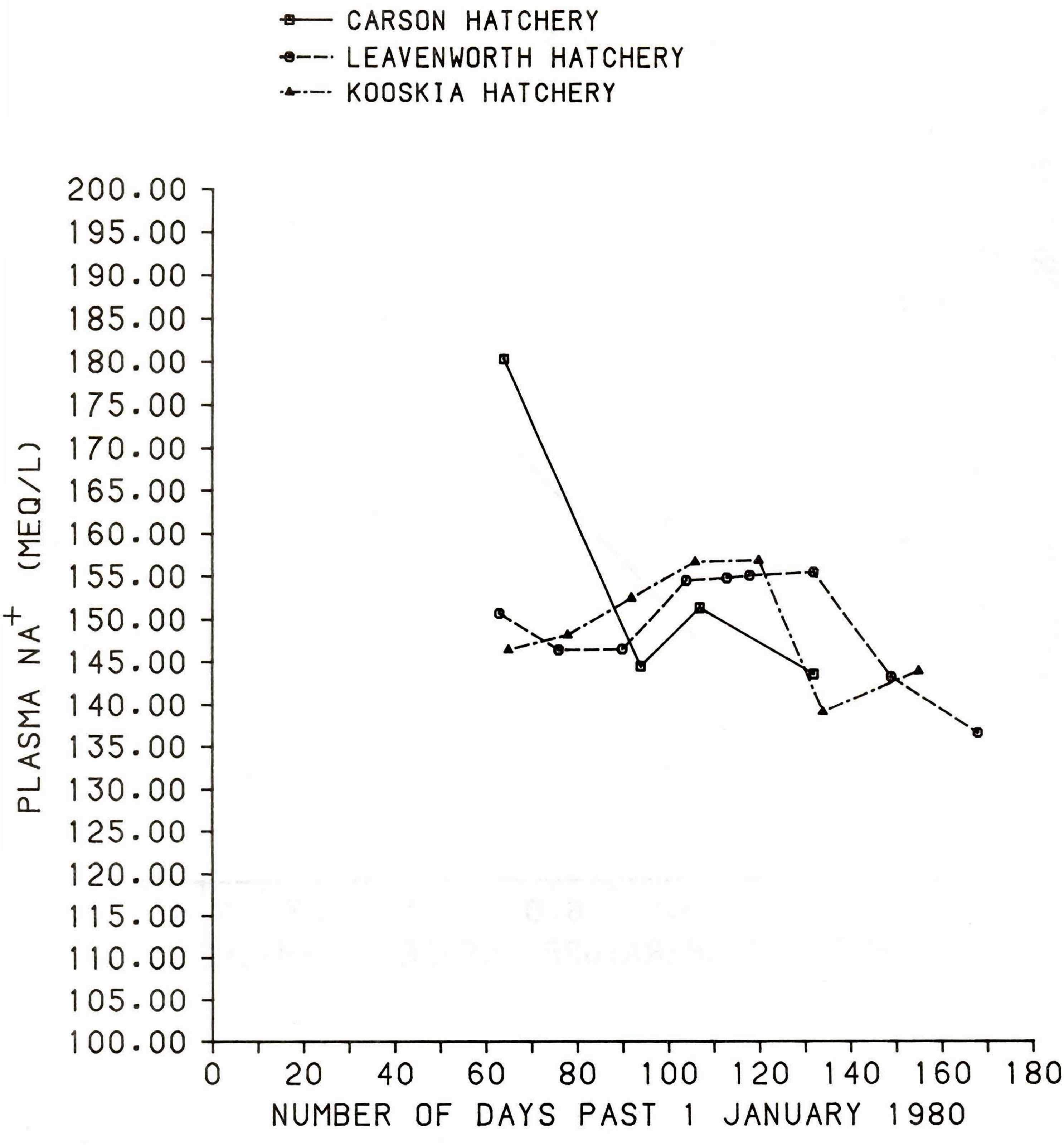


Figure 38.--Average plasma Na^{+} values for Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

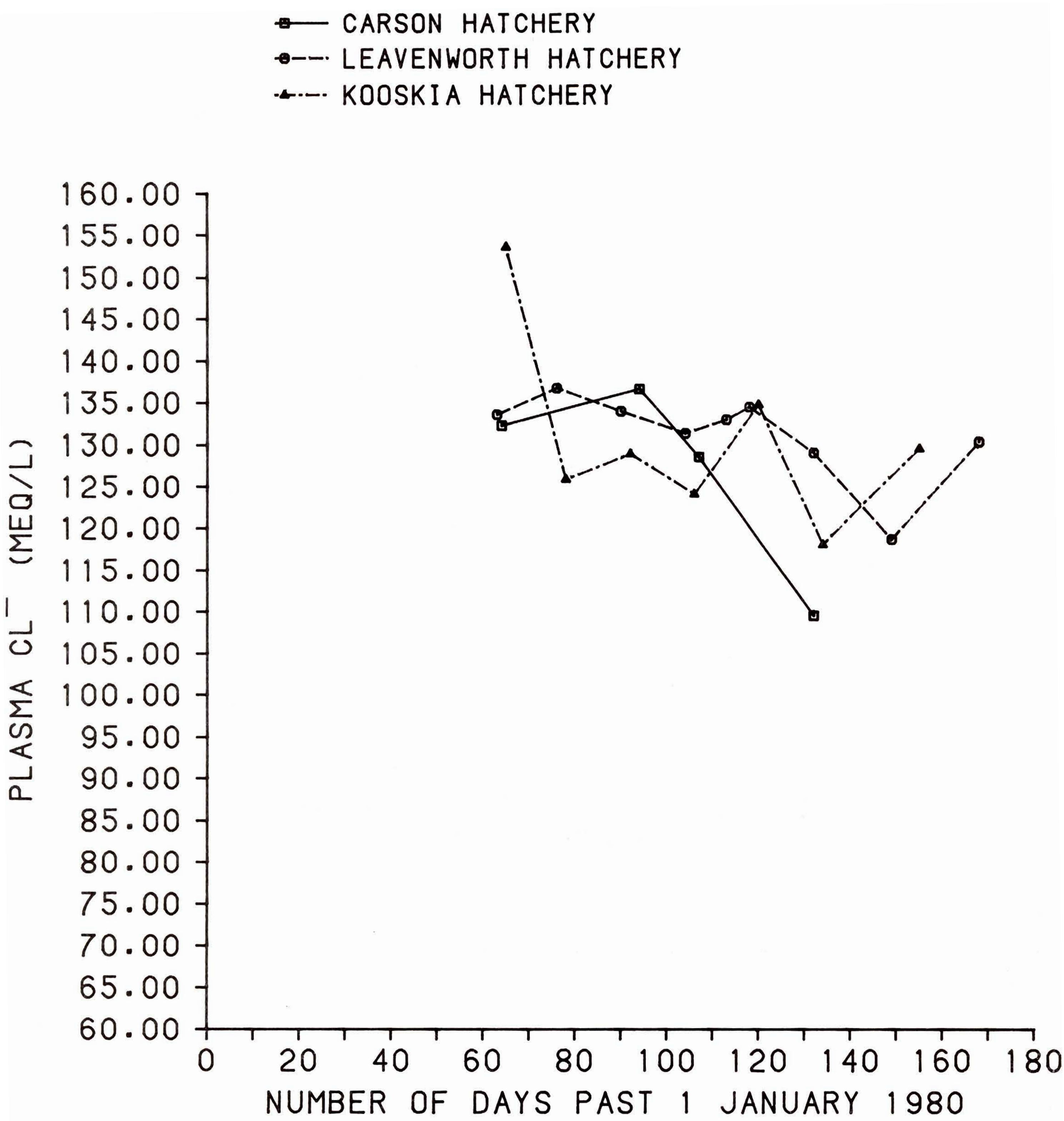


Figure 39.--Average plasma Cl^- values for Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

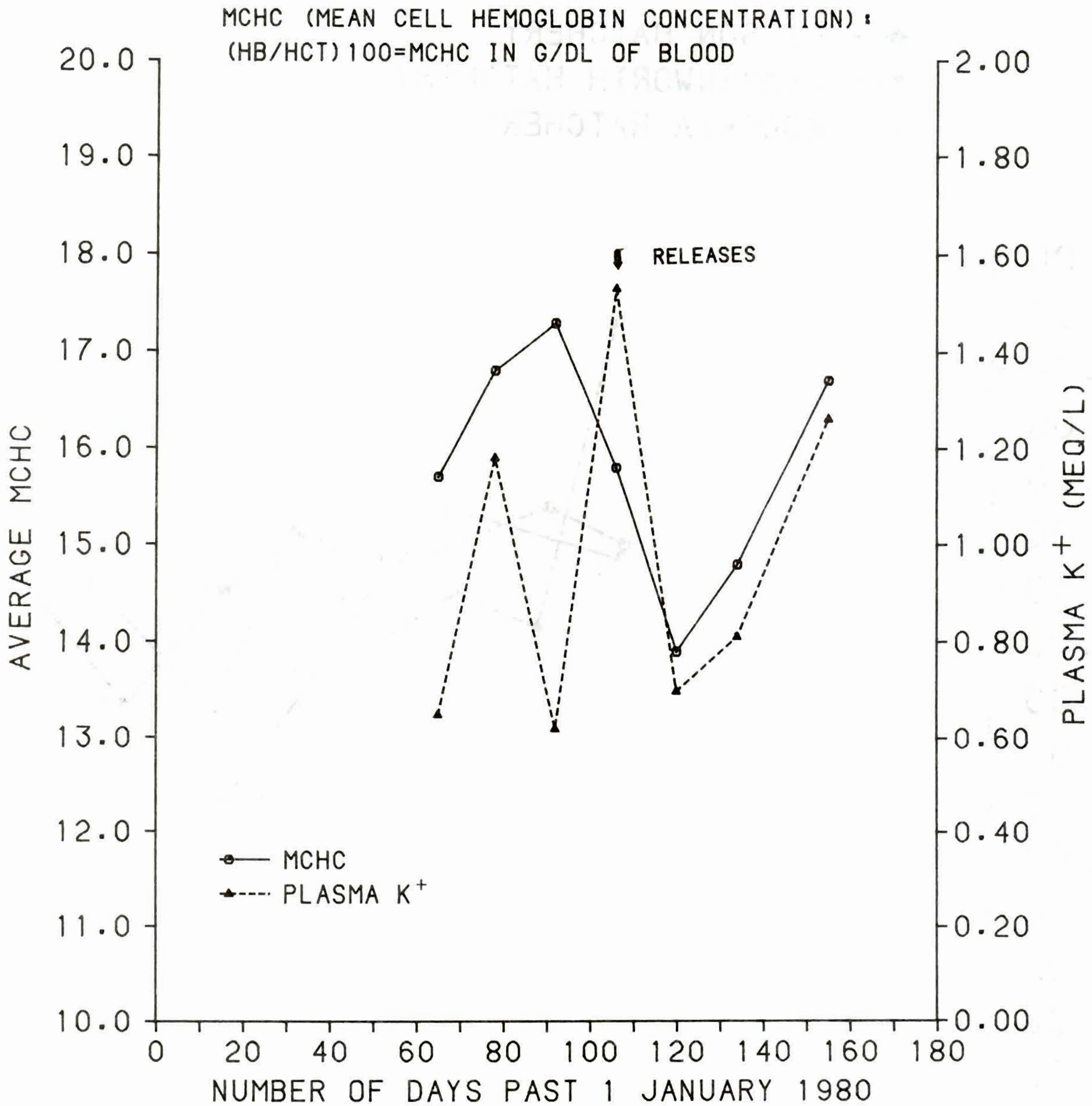


Figure 40.--Average plasma K^+ and mean cell hemoglobin concentration (MCHC) values for the Kooskia NFH spring chinook salmon during spring 1980.

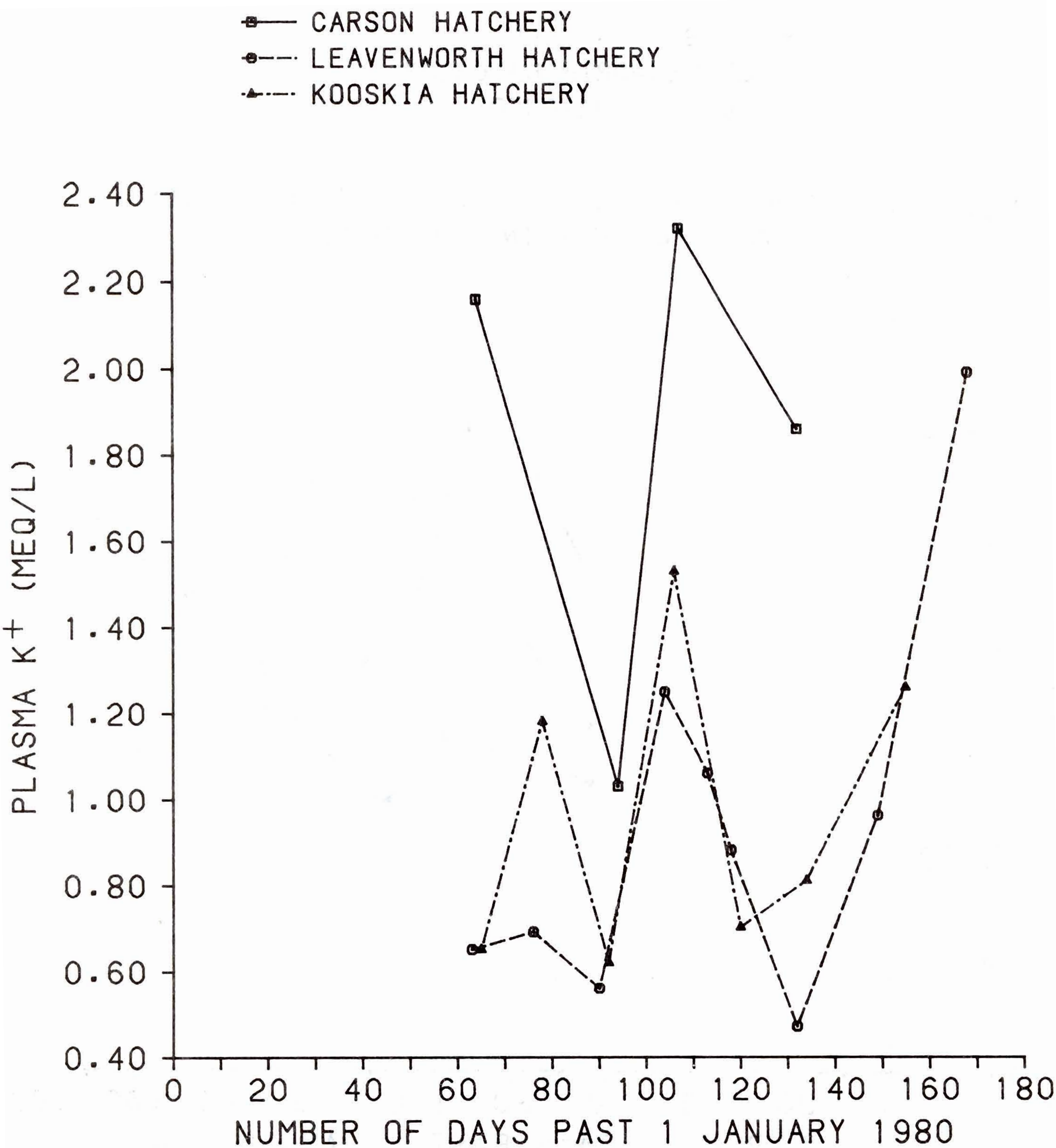


Figure 41.--Average plasma K^+ values for Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

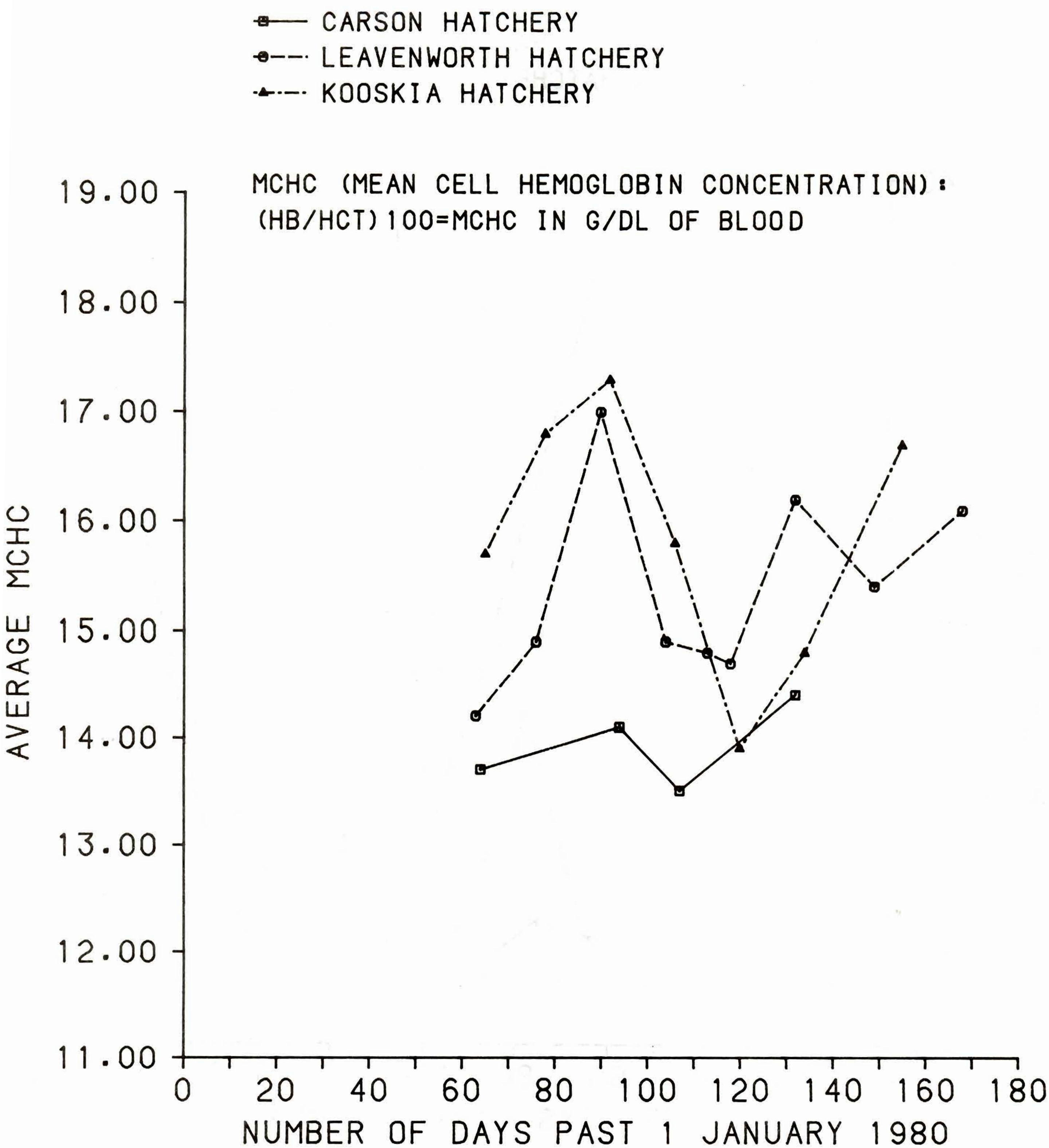


Figure 42.--Average mean cell hemoglobin concentrations (MCHC) for the Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

Hematology

Mean hematocrits of the Kooskia NFH fish were 39.1% ($\pm$ 8.2) and mean hemoglobins were 6.6 g/dl blood ($\pm$ 1.9) at release in 1978. Mean values were slightly higher at release in 1980 (fourth period), and the ranges were all within acceptable levels (Table 35). Steep declines in mean hematocrit and hemoglobin values did not occur until over 6 weeks post-release, and about 2 weeks after the maximum Na^+-K^+ ATPase activity (Table 35). In general, the data indicate that prior to, during, and after release, only a small percentage of fish showed any evidence of borderline hematology. Only 1.3% of the total fish sampled between early March (first period) and release (fourth period) had hematocrits less than 30%. This compares with about 8.3% for fish sampled at release in 1979. Less than 4% of the post-release fish held at the hatchery for the remainder of the sampling season had low hematocrits (< 30%). There were no high hematocrits (> 60%) for the first four periods, and about 6.7% in post-release fish that coincided with the peak of the Na^+-K^+ ATPase activity. About 2.5% of the pre-release and 13.3% of the post-release fish had slightly elevated hematocrits ($\geq$ 55%). There were highly significant correlations of individual hematocrits and hemoglobins ($P < 0.001$) in all seven periods, and percentages of below normal hemoglobins followed the same trends as hematocrits. There were no significant correlations between mean hematocrits and mean hemoglobins, nor between mean Hct, Hb, MCHC, and gill Na^+-K^+ ATPase.

IFAT-BKD

Specimens of Kooskia NFH spring chinook salmon from the first, third, and fifth sampling periods of 1980 were examined for the presence of BKD organisms by the IFAT (fish were released mid-way between the third and fifth periods). The total incidence of BKD for 1980 appears to be down substantially from 1978 (Table 36), and there is considerable variation in the percentage of fish with light intensity infections throughout the sampling period. Some of this may be due to sampling from different ponds. Data classifying fish with "severe" intensity of infection may be most meaningful. The IFAT-BKD tests indicate that approximately 2% of the samples were in this category in two of three sample periods (Table 36). Close observations were made of internal organs during all seven sampling periods for any gross pathology, especially BKD type lesions. There was an average of 2.4% of the fish with observed BKD type lesions for the seven periods of sampling in 1980, ranging from 0 to 5.0%. Using these data, a minimum estimate of 2 to 5% early mortality directly attributed to BKD could be expected.

Histopathology

A summary of pathological conditions observed is presented in Table 37. For comparative purposes, these data are further summarized with data from the other hatcheries in Table 9.

Compared to 1978 (Novotny and Zaugg 1979), Kooskia NFH fish were characterized by an increased incidence of eye lesions and both decreases and increases in gill lesions (Figure 43). As in Carson NFH spring chinook salmon, there was a pronounced decrease in certain gill lesions of intermediate (Class II) severity as the season progressed (Table 37), and the incidence of lesions of the olfactory sac was persistently high throughout the sampling period.

Table 36.--The incidence of BKD organisms in juvenile Kooskia Hatchery spring chinook salmon in 1978 and 1980 as determined by IFAT.

	% of fish with BKD bacteria in the kidney				
Date	Anterior kidney	Posterior kidney	Both kidneys	Totals	
1978 (at release)	11.7	8.3	70.0	90.0	
5 March 1980	13.0	14.8	44.4	72.2	(25.9 moderate 1.9 severe)[a]
2 April 1980	1.8	0.0	1.8	3.5%	(100 light)[b]
30 April 1980	16.1	12.5	23.2	51.8	(12.5 moderate 1.8 severe)[c]

a/ moderate = 10-99 organisms/150 microscopic fields.

b/ light = 1-9 organisms/150 microscopic fields.

c/ severe = $\bar{>}$ 100 organisms/150 microscopic fields.

Table 37.--Pathological conditions observed in 1980 Kooskia Hatchery spring chinook salmon and their percentage of incidence.[a]

Organ and pathology	Incidence (%) Period 1 (severity)[b]				Period 3 (severity				Period 5 (severity)			
	I	II	III	total	I	II	III	total	I	II	III	total
Eye												
skeletal muscle lesions	15.0	0	0	15.0	33.0	0	0	33.0	45.0	0	0	45.0
Gills												
increased numbers of lymphocytes	81.7	5.0	0	86.7	56.7	6.7	0	63.3	40.0	10.0	1.7	51.7
epithelial cell formation	50.0	35.0	0	85.0	55.0	18.3	0	78.3	63.3	5.0	0	68.3
vascular telangiectasis of secondary lamellae	15.0	0	0	15.0	31.7	0	0	31.7	20.0	0	0	20.0
Olfactory sac												
focal mononuclear cell infiltration	76.7	3.3	0	80.0	83.3	6.7	0	90.0	81.7	8.3	1.7	91.7

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

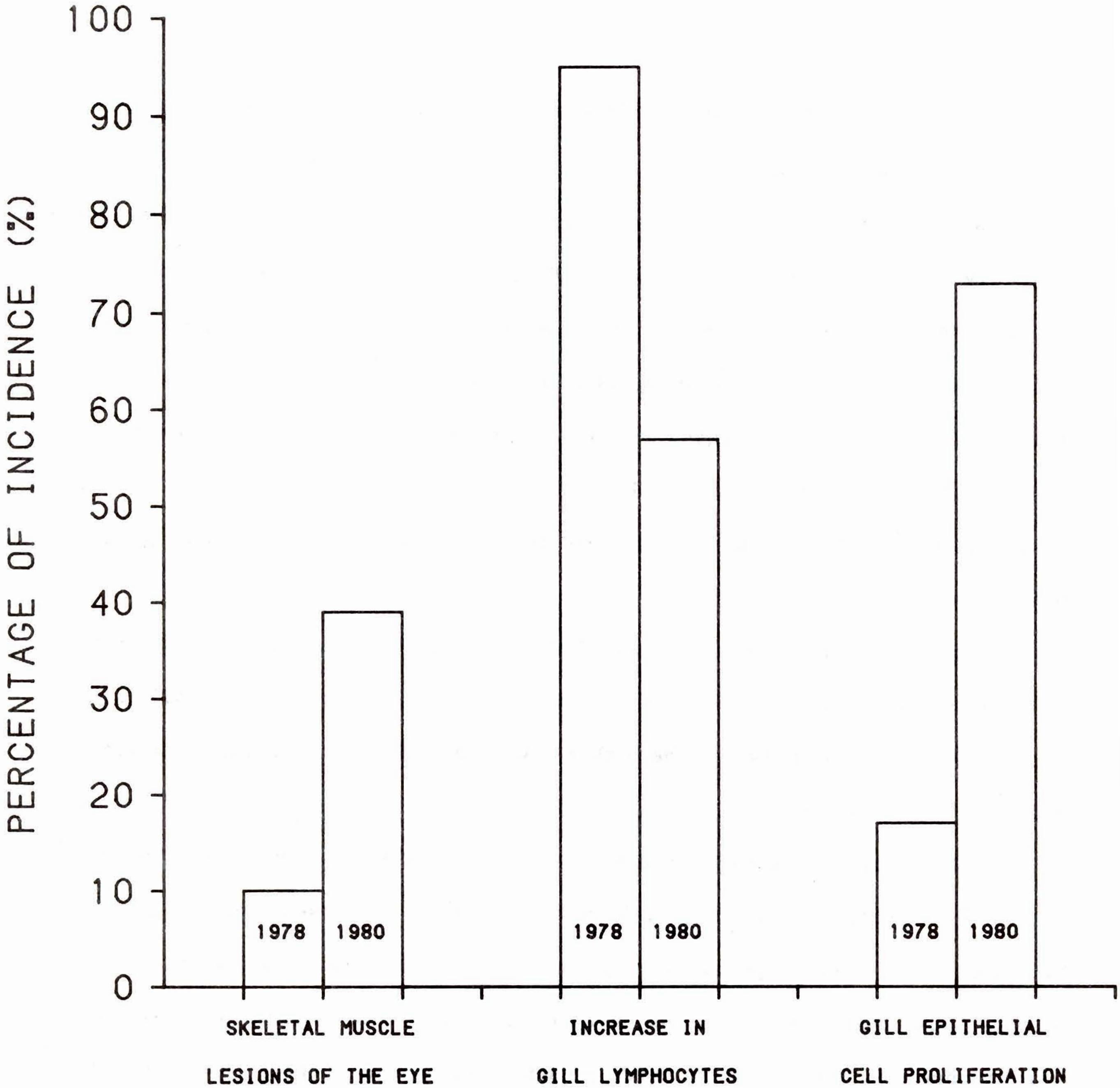


Figure 43.--Changes in the percentage of incidence in certain tissue pathology of Kooskia NFH spring chinook salmon in 1978 and 1980.

Summary

Serial sampling of Kooskia NFH spring chinook salmon in 1980 indicated that general health of the fish was good throughout the sampling season, and that clinical evidence of any disease related problems was low and probably reduced from that of 1978. Field notes indicate that a group of Kooskia NFH fish originating from Carson NFH were released from Kooskia NFH 1 week before the main releases, and there were undocumented reports that this early (Carson NFH origin) release group was suffering from anemia and a high incidence of obvious BKD lesions. Our data suggest that early mortalities directly attributable to BKD in the normal release groups should be approximately 2 to 5%.

Mean hematocrits of Carson, Leavenworth, and Kooskia NFH spring chinook salmon data suggest that throughout the season, Kooskia NFH fish were approximately between the other two, presenting a normal, healthy appraisal (Figure 44).

However, it would appear from gill Na^{+}-K^{+} ATPase and plasma electrolyte data, that the fish may have been released before a high percentage of the population smolted. A comparison of gill Na^{+}-K^{+} ATPase data from the same three hatcheries (Figure 36) shows a remarkable coincidence in the profiles and presents sufficient data in itself to indicate that holding Kooskia NFH fish until at least 1 May would have been the best choice.

Since none of the samples had adequately elevated Na^{+}-K^{+} ATPase levels at release, we must conclude that the percentage of smolting was very low, and no estimates can be given.

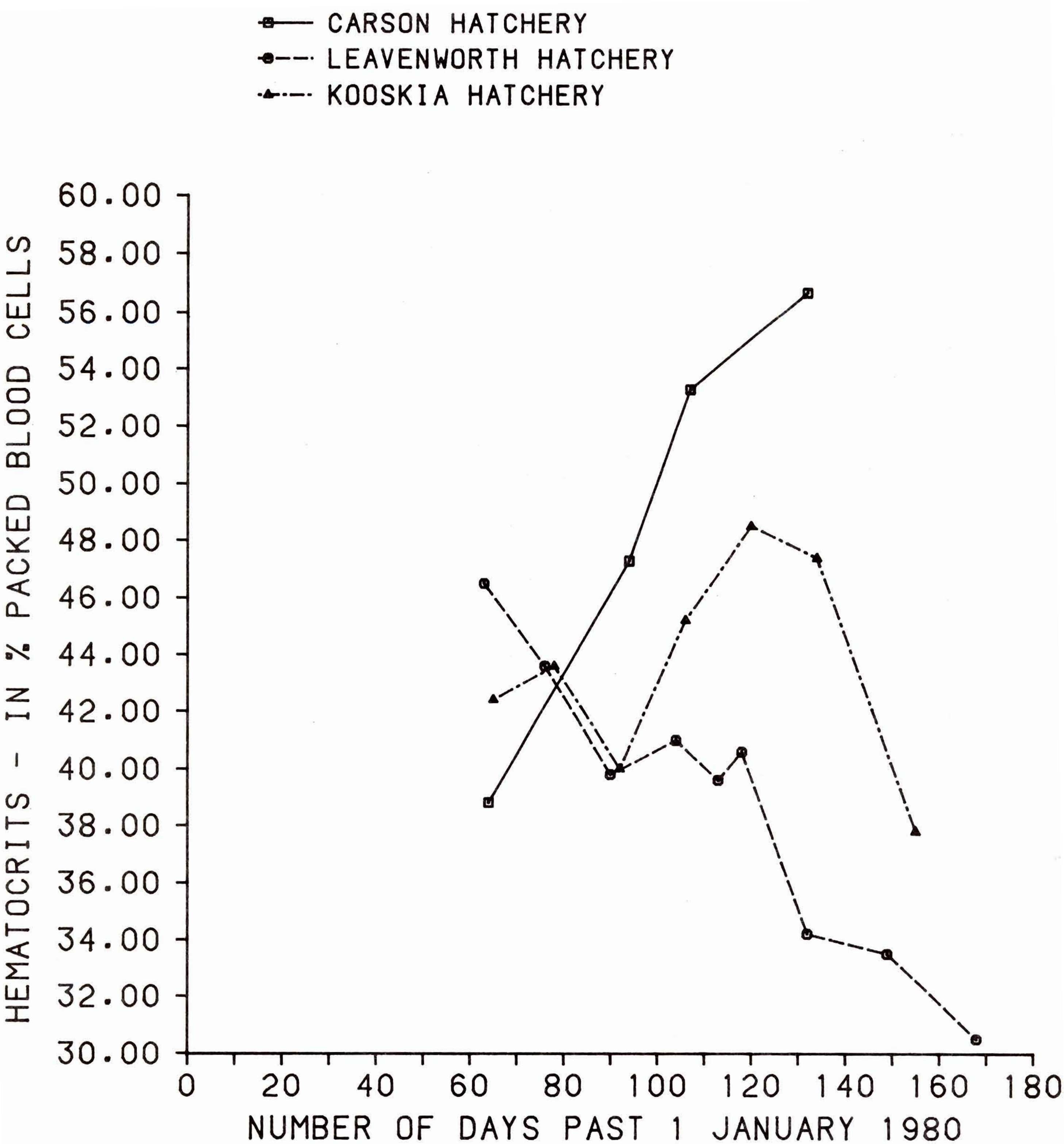


Figure 44.--Average hematocrit values for Carson, Leavenworth, and Kooskia NFH spring chinook salmon during spring 1980.

Rapid River Hatchery (IDFG)

General

Sampling of spring chinook salmon from the earthen rearing ponds at The Idaho Fish and Game Department's (IDFG) Rapid River Hatchery began in early March and continued into mid-May at 2-week intervals, for a total of six periods. The fish were allowed to migrate volitionally. Migration began in early April, and from 17 April (fourth period) post-release fish were held in a temporary circular tank at the hatchery. The main ponds were drained about 1 May for annual maintenance, and at this time any residual fish were flushed out.

Sampling from the ponds without stressing fish presented a problem, as physical conditions were not suitable for crowding. Sampling was accomplished by dropping a lift-net below an automatic feeder in the middle of the pond, hand broadcasting food over the net, and then rapidly raising the net. Usually over 500 fish could be trapped, and from this sample approximately 20 fish were dipped out for destructive analysis. This was repeated three times during the course of the day.

Field notes indicate that erythromycin phosphate was injected into Rapid River Hatchery adults prior to spawning and also to treat eggs at fertilization to reduce the vertical transmission of BKD.

Plasma samples were pooled by groups of three fish (along with the gill samples for Na^+-K^+ ATPase analysis) until Periods 5-6, when individual plasmas were used.

Data from six sampling periods are presented in Table 38. The peak of emigration was estimated to be 10 April, and the samples from Periods 4-6

Table 38.--Summary data for the spring (1980) sampling of Rapid River Hatchery spring chinook salmon with means, standard deviations ( ), and ranges. Sample size = 60.

	Period					
	1	2	3 (peak of emigration)	4	5	6
Date	6 Mar 80	21 Mar 80	3 Apr 80	17 Apr 80	1 May 80	15 May 80
Days>Jal [a]	66	79	93	107	121	134
Temp. °C [b]	3.5	4.0	5.0	6.0	7.5	8.5
Avg. Fk Ln [c]	126.6	130.4	135.7	133.2	136.5	143.7
	(5.0)	(7.4)	(3.7)	(9.5)	(9.1)	(4.9)
(Range)	116.7-135.0	116.3-142.3	130.7-141.3	116.7-147.7	122.3-152.3	136.7-152.0
Avg. ATP Fk Ln [d]	126.6	130.4	135.7	133.2	136.5	143.7
	(5.0)	(7.4)	(3.7)	(9.5)	(9.1)	(4.9)
(Range)	116.7-135.0	116.3-142.3	130.7-141.3	116.7-147.7	122.3-152.3	136.7-152.0
Avg. ATP [e]	8.4	9.5	12.6	10.8	10.9	7.9
	(1.4)	(1.0)	(3.6)	(2.0)	(1.9)	(2.8)
(Range)	6.0-10.1	8.1-10.9	8.6-20.2	7.5-14.0	7.8-14.0	5.1-13.5
Avg. Hct [f]	40.0	41.8	38.2	42.2	44.5	49.6
	(6.9)	(6.0)	(5.9)	(7.6)	(8.6)	(7.4)
(Range)	9-52	26-53	25-55	18-60	21-65	35-65
Avg. Hb [g]	4.8	5.2	5.9	5.9	5.9	7.4
	(1.1)	(1.0)	(1.1)	(1.5)	(1.1)	(1.2)
(Range)	1.0-7.0	2.0-7.3	2.6-8.1	0.7-9.0	3.5-8.1	5.0-10.7
Avg. MCHC [h]	12.0	12.5	15.7	14.0	13.4	15.3
	(1.4)	(1.9)	(3.1)	(3.0)	(3.0)	(2.7)
(Range)	8.8-15.6	7.0-17.8	7.6-26.0	3.71-19.6	8.0-23.4	10.4-20.9
Avg. Na^+ [i]	159.6	146.2	161.7	125.2	130.9	116.0
	(10.2)	(16.9)	(4.0)	(17.6)	(16.3)	(20.0)
(Range)	136-182	112-173	152-167	104-160	83-155	69-165
Avg. K^+ [j]	0.86	1.02	0.68	0.59	0.51	0.61
	(0.61)	(0.40)	(0.32)	(0.42)	(0.36)	(0.50)
(Range)	0.37-2.75	0.47-1.86	0.34-1.44	0.19-1.70	0.23-2.00	0.24-1.95
Avg. Cl^- [k]	135.4	133.3	133.0	86.9	113.0	93.1
	(10.1)	(11.8)	(4.6)	(12.1)	(21.5)	(13.1)
(Range)	122-158	107-151	123-139	70-119	60-163	63-111
Na^+/Cl^- [l]	1.18	1.10	1.22	1.41	1.18	1.24
	(0.10)	(0.13)	(0.03)	(0.09)	(0.15)	(0.10)
(Range)	1.03-1.41	0.86-1.31	1.16-1.29	1.28-1.57	0.85-1.75	1.02-1.54

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

(Table 38) were collected from fish held back in circular tanks. Periods 5-6 could be considered "post-emigration."

Field notes indicate that Dr. G.W. Klontz[4/] suspected some epistylus infestations in early March, and we noted a small number of "graybacks" during the second sampling period. By the fourth period, very few parred fish and no BKD lesions were noted. The fish looked good and the scales were loose.

Figure 45 is a profile of water temperatures in the ponds at Rapid River Hatchery as measured during the sampling periods. Figure 46 plots average fork lengths of Rapid River hatchery fish as measured from our sampling. The apparent decline in growth and growth rate after the third period may be an artifact resulting from larger, smolting fish emigrating from the pond first.

Gill Na^{+}-K^{+} ATPase

There is difficulty in following trends of gill Na^{+}-K^{+} ATPase (or any of the other parameters) in Rapid River Hatchery spring chinook salmon because fish were allowed to migrate volitionally, and the only totally captive population from which samples could be taken was not established until the fourth period. Figure 47 profiles the Na^{+}-K^{+} ATPase values. Note that the curve increases rapidly and then declines between the third and fourth periods. If a major migration of smolting fish had occurred, the emigrating individuals probably had the highest Na^{+}-K^{+} ATPase values. In the third period, 30% of the Na^{+}-K^{+} ATPase samples were

[4/] Professor of fisheries, University of Idaho, Moscow, Idaho.

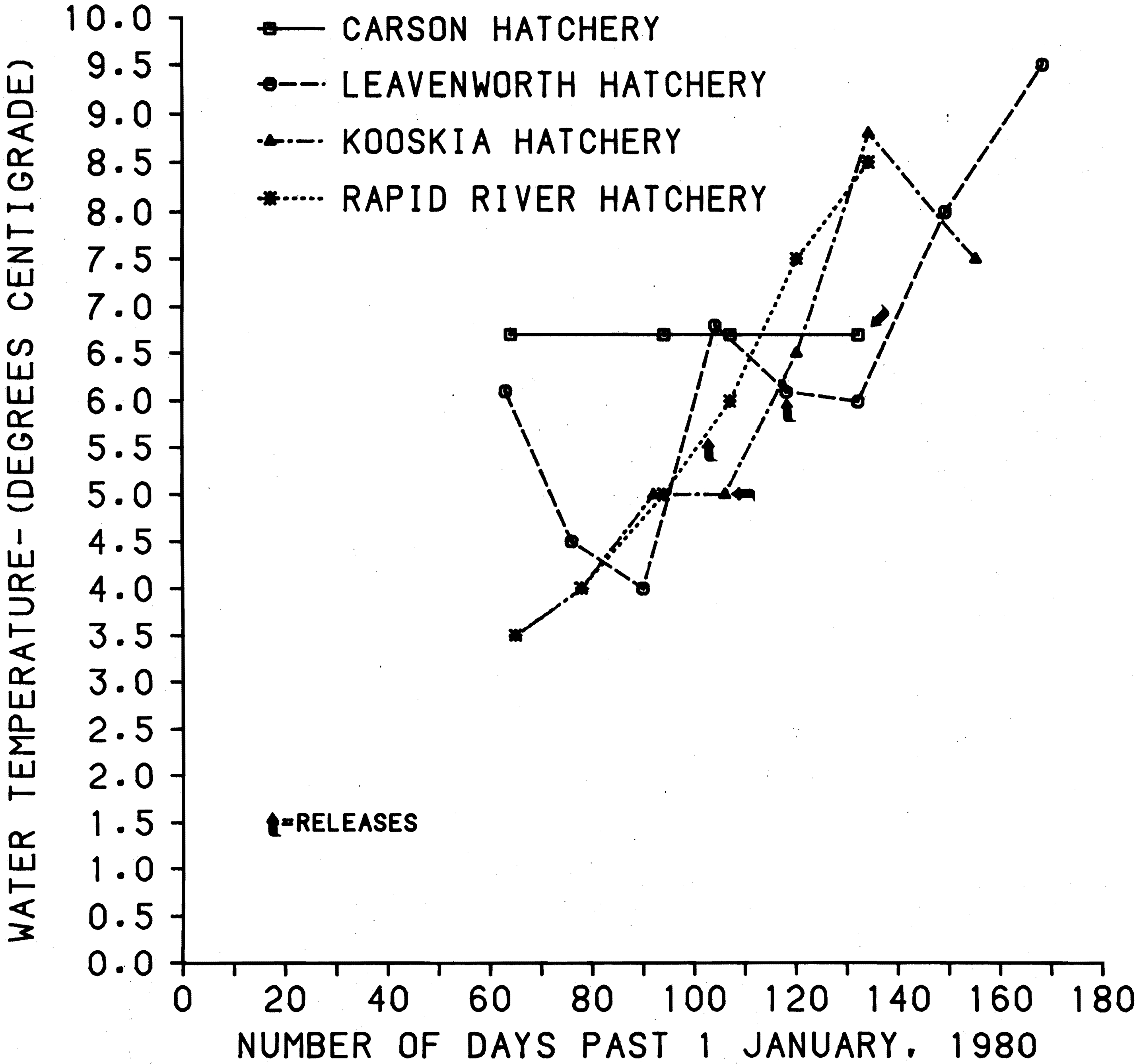


Figure 45.--Water temperatures measured at Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery during spring 1980.

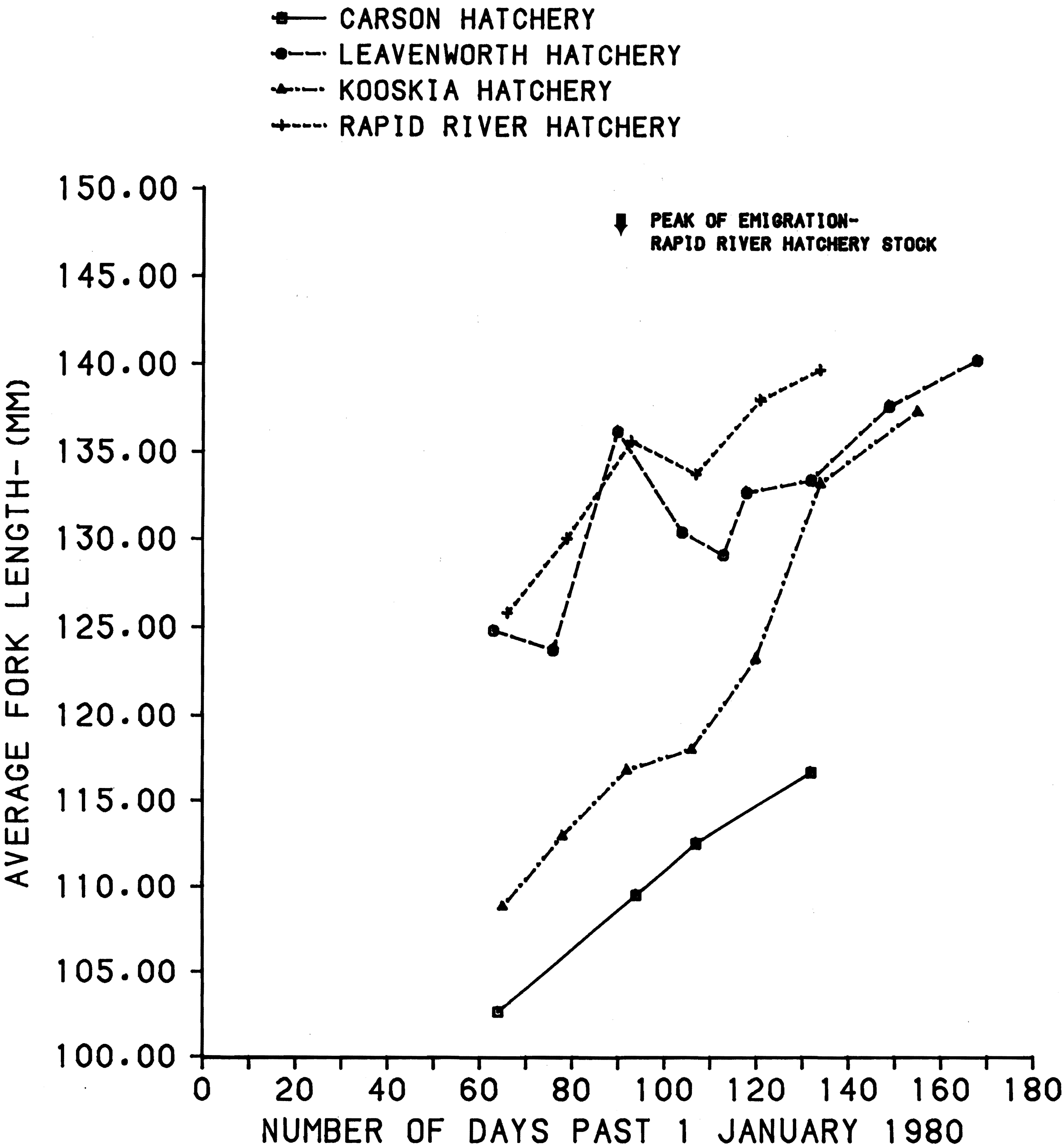


Figure 46.--Mean fork lengths of spring chinook salmon sampled from Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery during spring 1980.

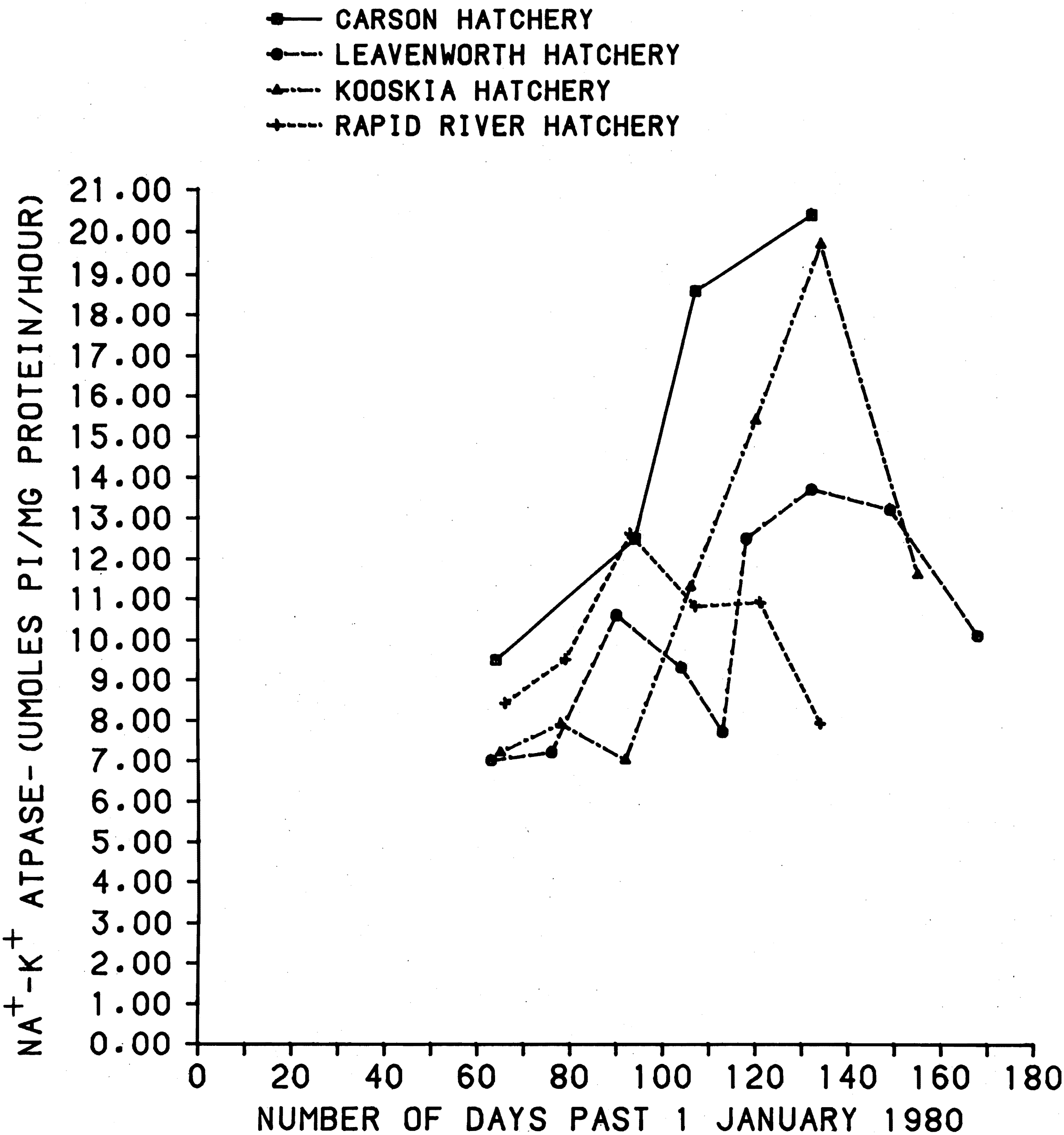


Figure 47.--Mean gill Na^{+}-K^{+} ATPase values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

greater than 15.0 u moles Pi/mg protein/hour. In the fourth period, none of the samples was greater than 14.0 u Pi/mg protein/hour. There were no positive correlations between mean gill Na^+-K^+ ATPase values or other parameters during the sampling season, or during individual periods. From the profile presented (Figure 47), there definitely appears to be a post-smolting decline in Na^+-K^+ ATPase values after the fifth period which may have been reduced by a change in environments. A "best guess" would be that at least 30% of the fish sampled were smolting at the beginning of the migration period (3), and that this percentage increased during the next 2 weeks.

Plasma Electrolytes

Mean plasma Na^+ values (Table 38) were occassionally higher than the expected (Table 25), and the mean plasma Cl^- and K^+ values were frequently lower. Mean chloride values on two occasions, for example, ranged from 10.5 to 16.3% lower than the lowest Cl^- values reported in Table 25, and on four occasions mean plasma K^+ values ranged from 16 to 37.5% lower than the lowest values reported in Table 25.

Mean plasma Na^+ and Cl^- levels declined rapidly during the peak of migration (Figures 48 and 49), and mean plasma K^+ concentrations were well into a decline at the same time (Figure 50). The mean Na^+/Cl^- ratio (which is, again, a measure of the maximum divergence of plasma Na^+ and Cl^-) increased sharply to a peak value at the same time (Table 38). The key stress indicators (elevated plasma K^+ amd MCHC values) had peaked and were in a sharp decline during this major migration period (Figures 50 and 51).

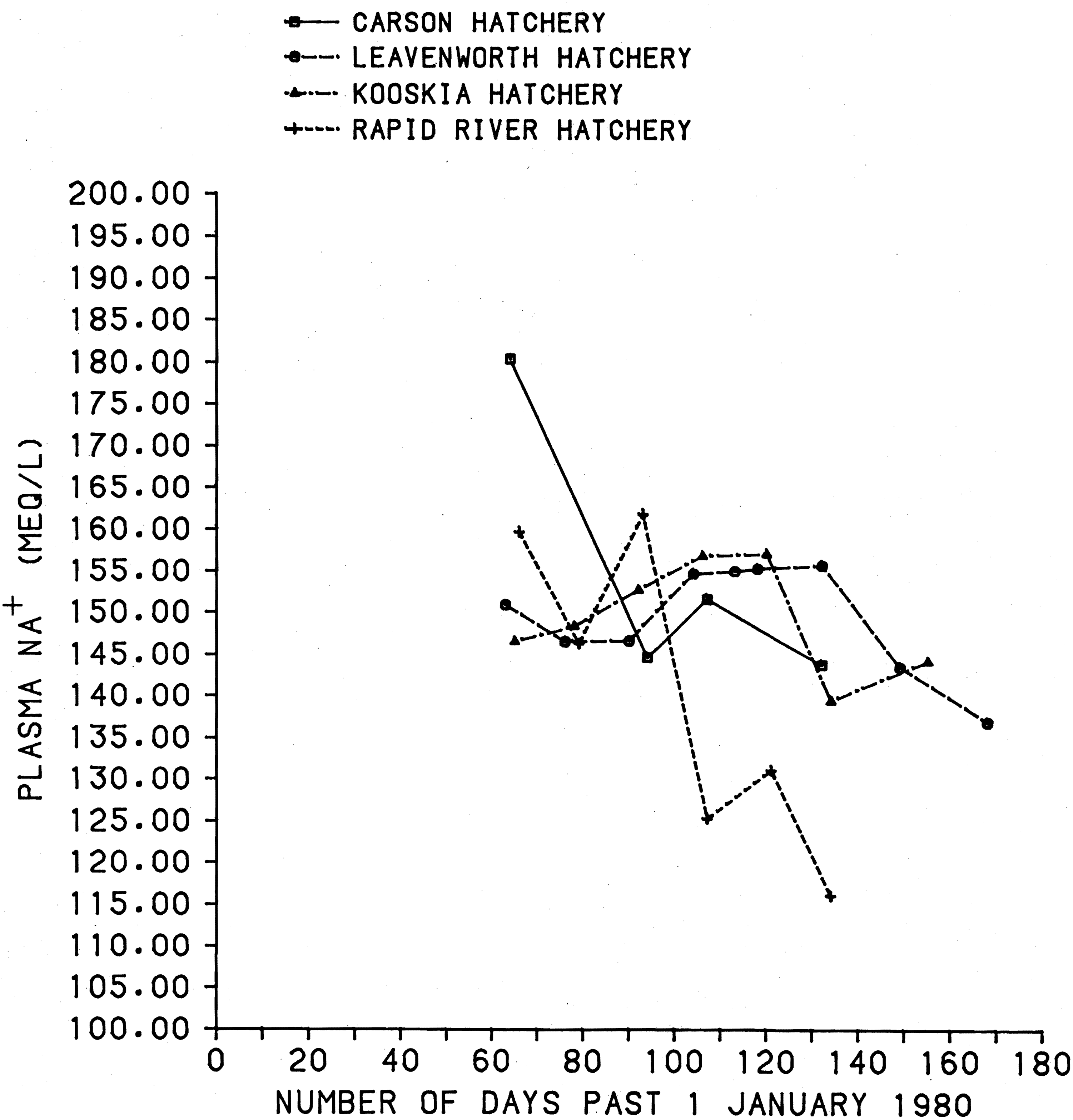


Figure 48.--Mean plasma Na^+ values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

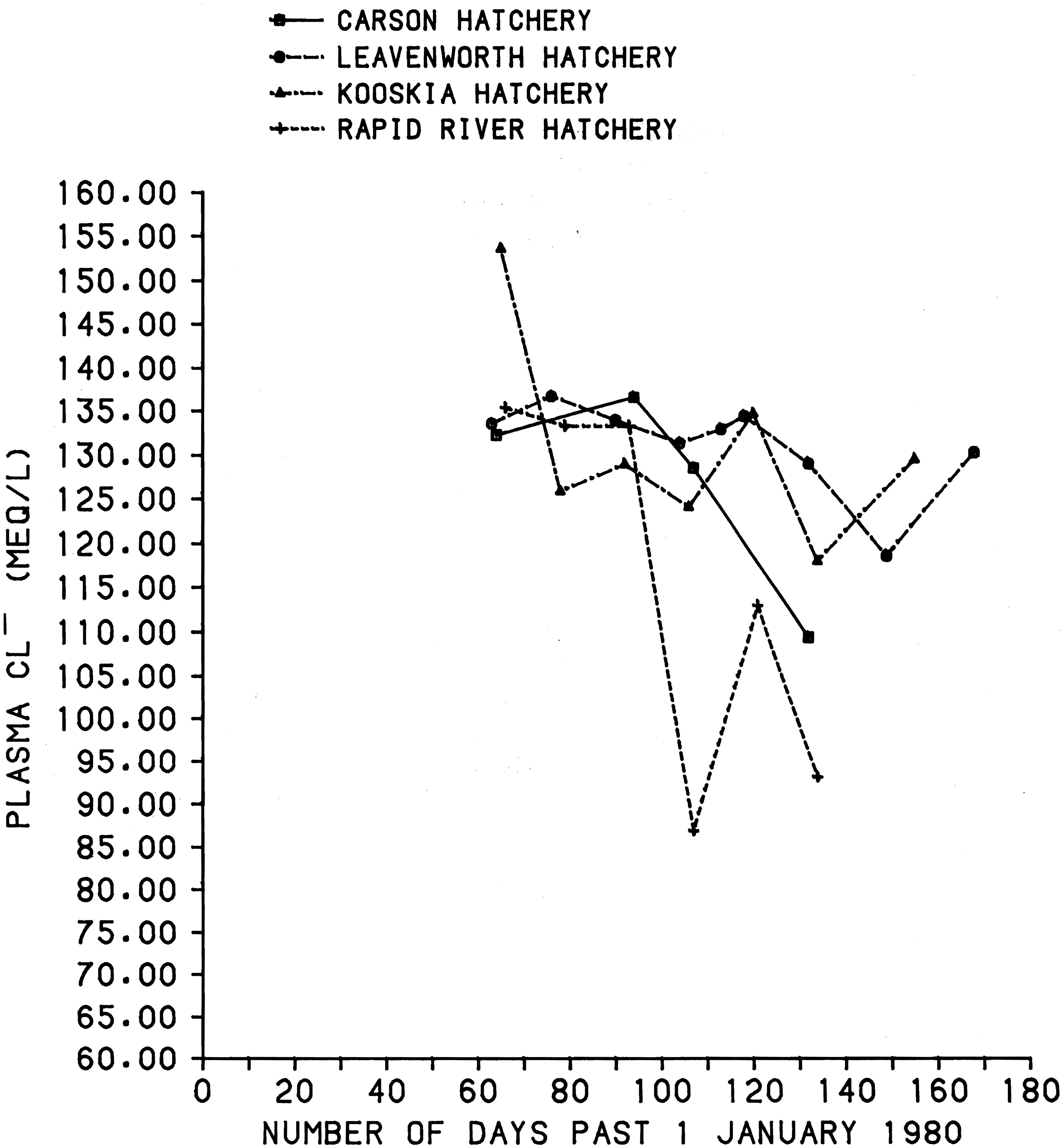


Figure 49.--Mean plasma Cl^- values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

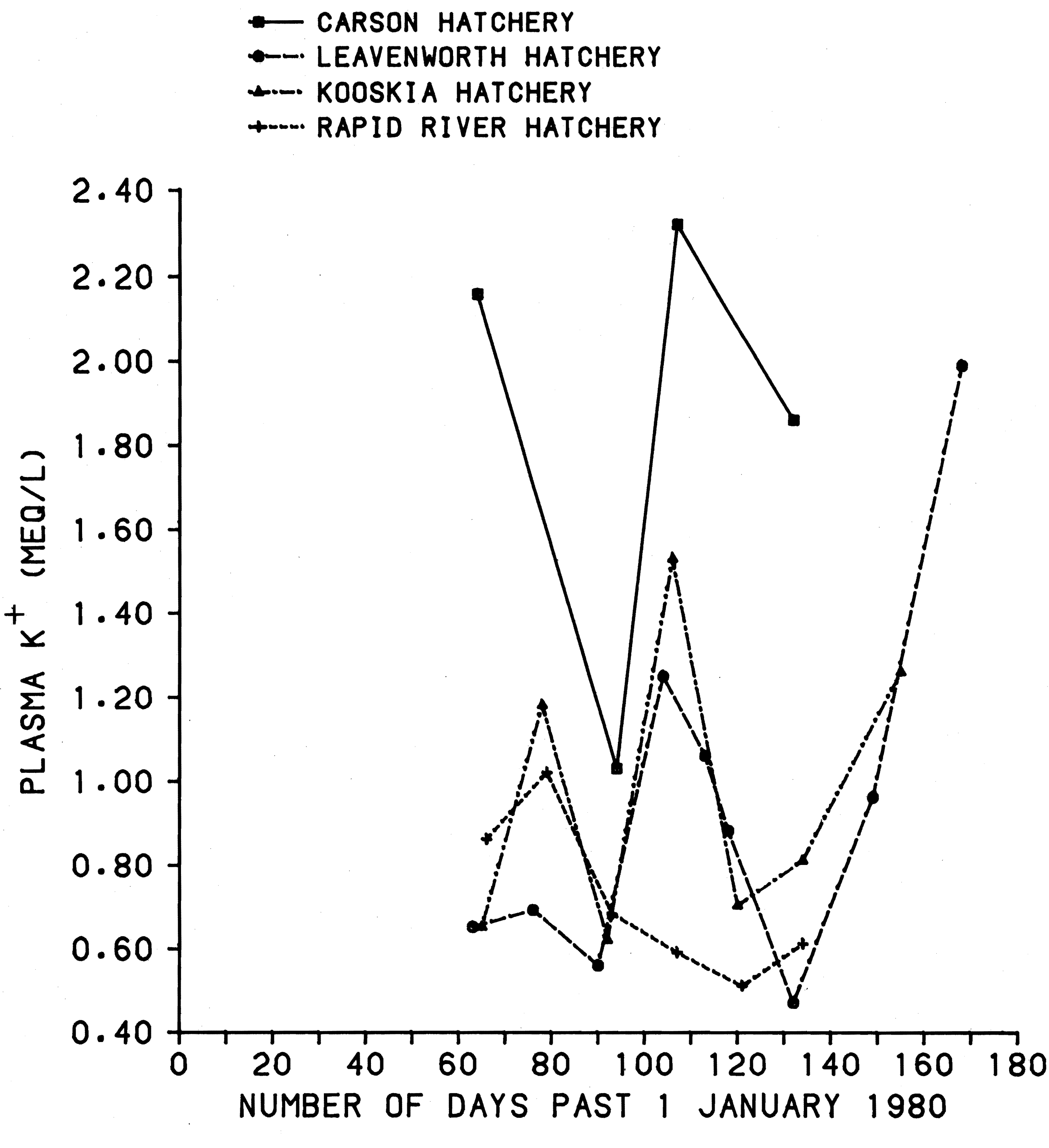


Figure 50.--Mean plasma K^+ values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

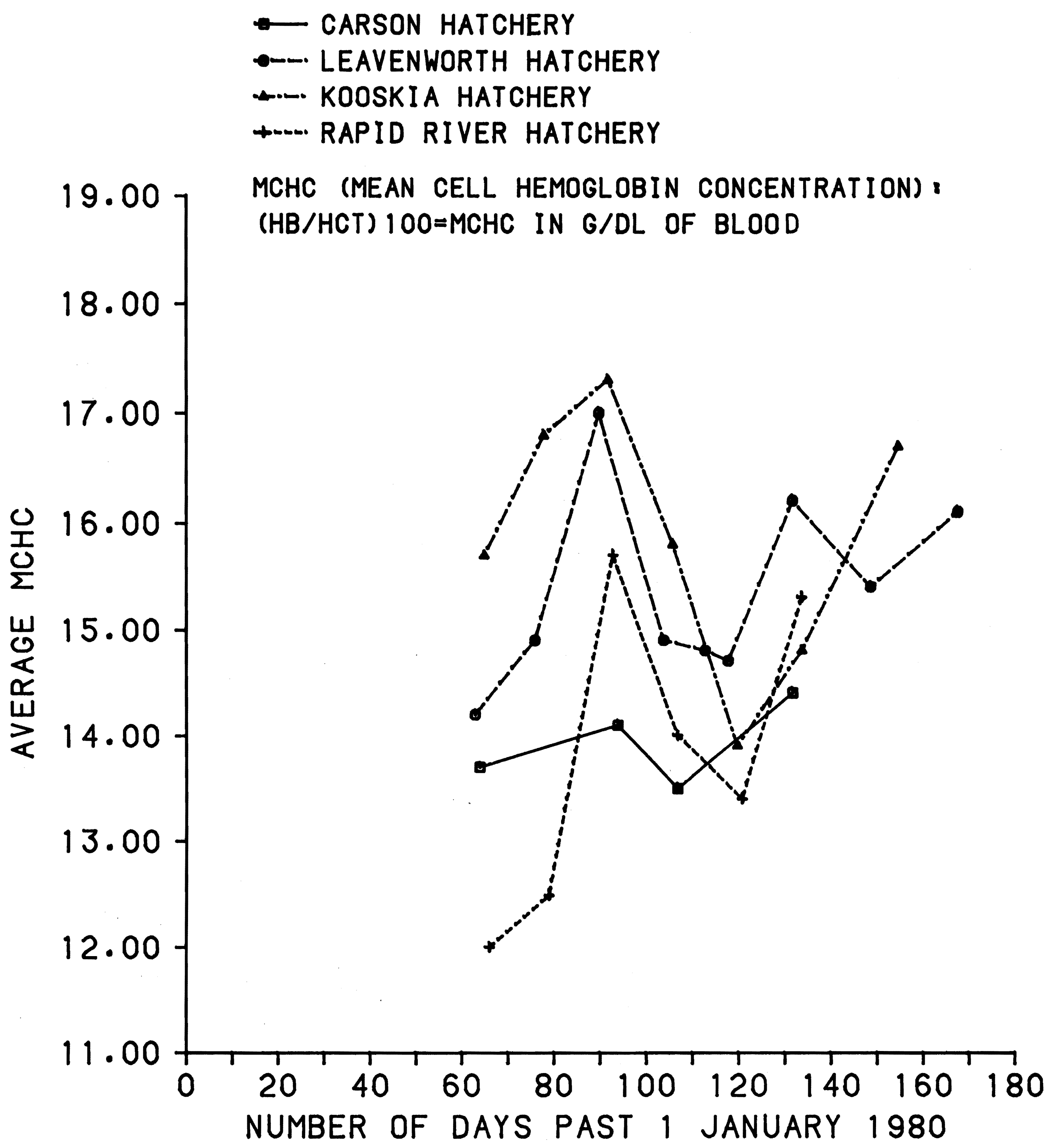


Figure 51.--Average mean cell hemoglobin concentrations (MCHC) of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

There were no correlations between the average gill Na^+-K^+ ATPase value and any of the average plasma electrolytes. There was a significant positive correlation between mean plasma Cl^- and mean plasma Na^+ values (Figure 52), a significant negative correlation between mean plasma Na^+ and water temperatures (Figure 53), and between mean plasma Na^+ and mean hematocrits (Figure 54).

There were no significant correlations between individual plasma Na^+ and Cl^- values until the third period ($r = 0.615$; $P < 0.005$), early in April. Correlations of Na^+ and Cl^- from that point increased, and ranged from $r = 0.8$ to 0.9 ($P < 0.001$). Correlations between individual plasma K^+ and the Na^+ and Cl^- values were significant only between the third and fourth periods ($r = 0.6$-0.7; $P < 0.01$-0.02).

Hematology

Mean hematocrits and hemoglobins of Rapid River Hatchery spring chinook salmon were all within normal ranges throughout the 1980 spring sampling season (Table 38) and showed a general increase as the season progressed (Figures 55 and 56). There were significant positive correlations between the hatchery water temperature and mean hematocrits ($r = 0.840$; $P < 0.05$) and mean hemoglobins ($r = 0.882$; $P < 0.02$) suggesting that these parameters are positively influenced by water temperature in this stock (Figures 57 and 58).

There was no significant correlation between mean hematocrit and hemoglobin values. Individual hematocrits and hemoglobins were all positively correlated throughout the sampling season (Table 39). Although mean plasma Na^+ values and mean hematocrits were significantly correlated (Figure 54), these relationships could not be shown for individual fish.

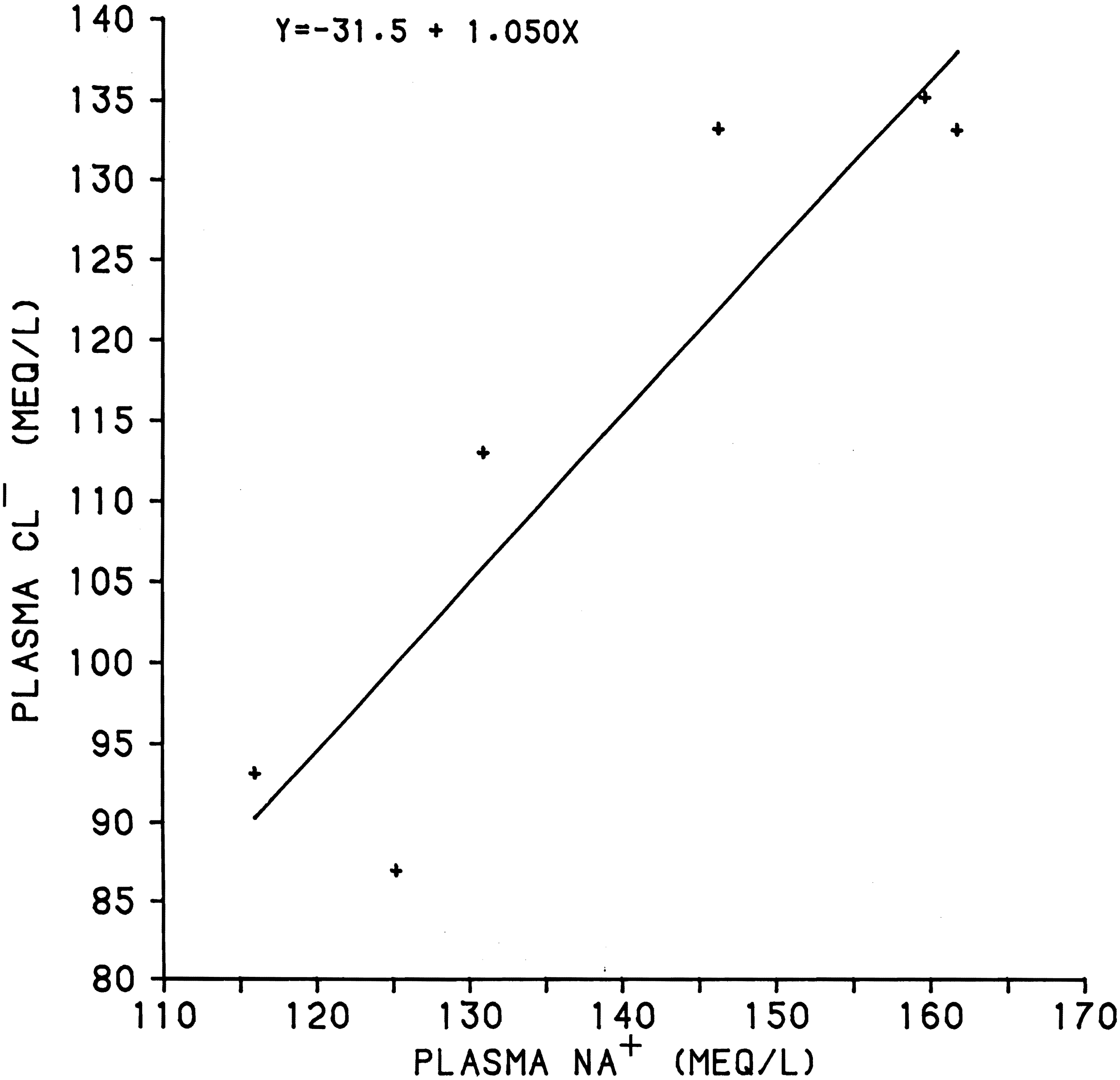


Figure 52.--Regression of mean plasma Cl^- values on mean plasma Na^+ values of Rapid River Hatchery spring chinook salmon during spring 1980. $r = 0.915$; $P < 0.02$.

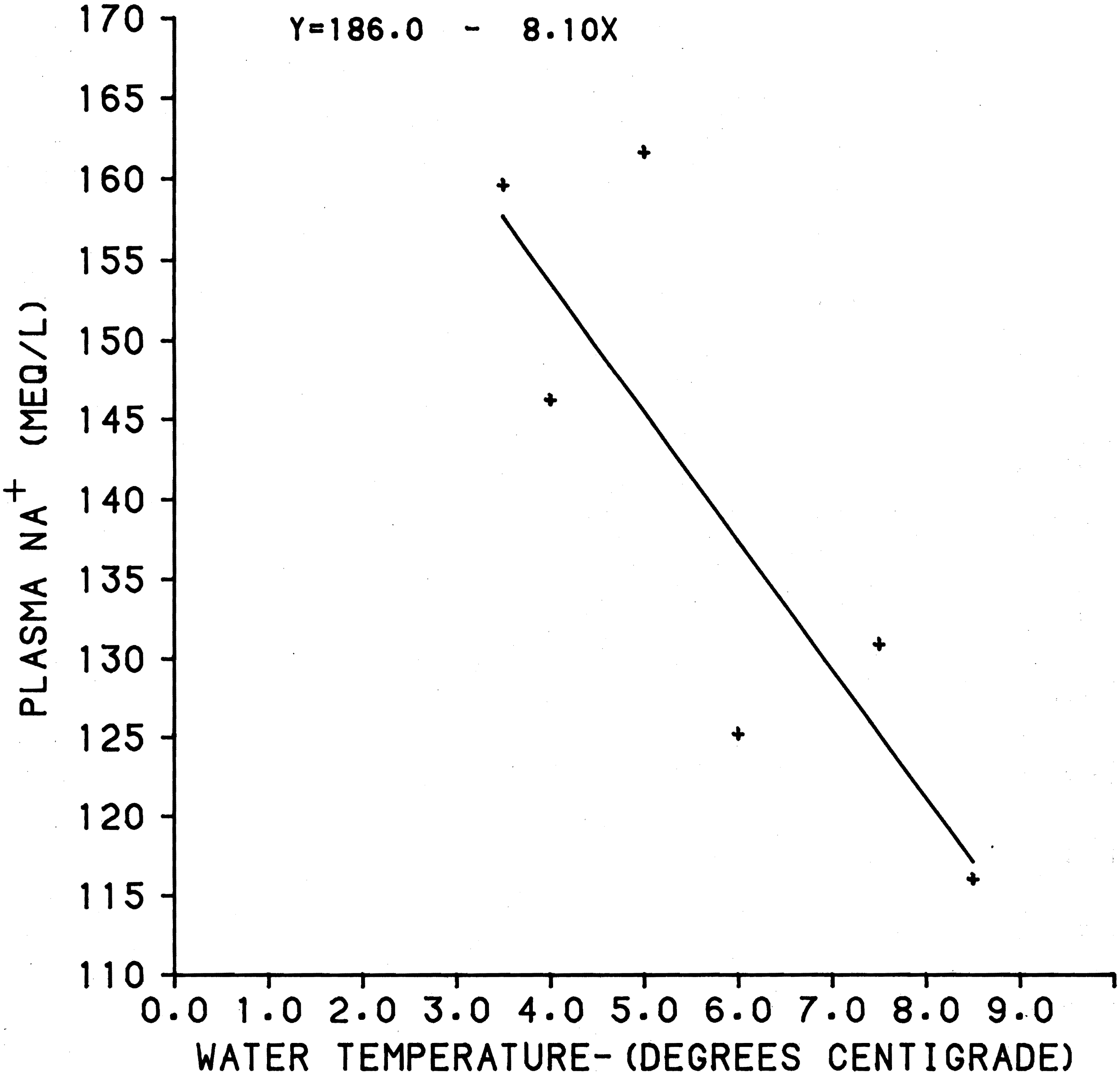


Figure 53.--Regression of mean plasma Na^+ values of Rapid River Hatchery spring chinook salmon on water temperature during spring 1980. $r = -0.847$; $P < 0.05$.

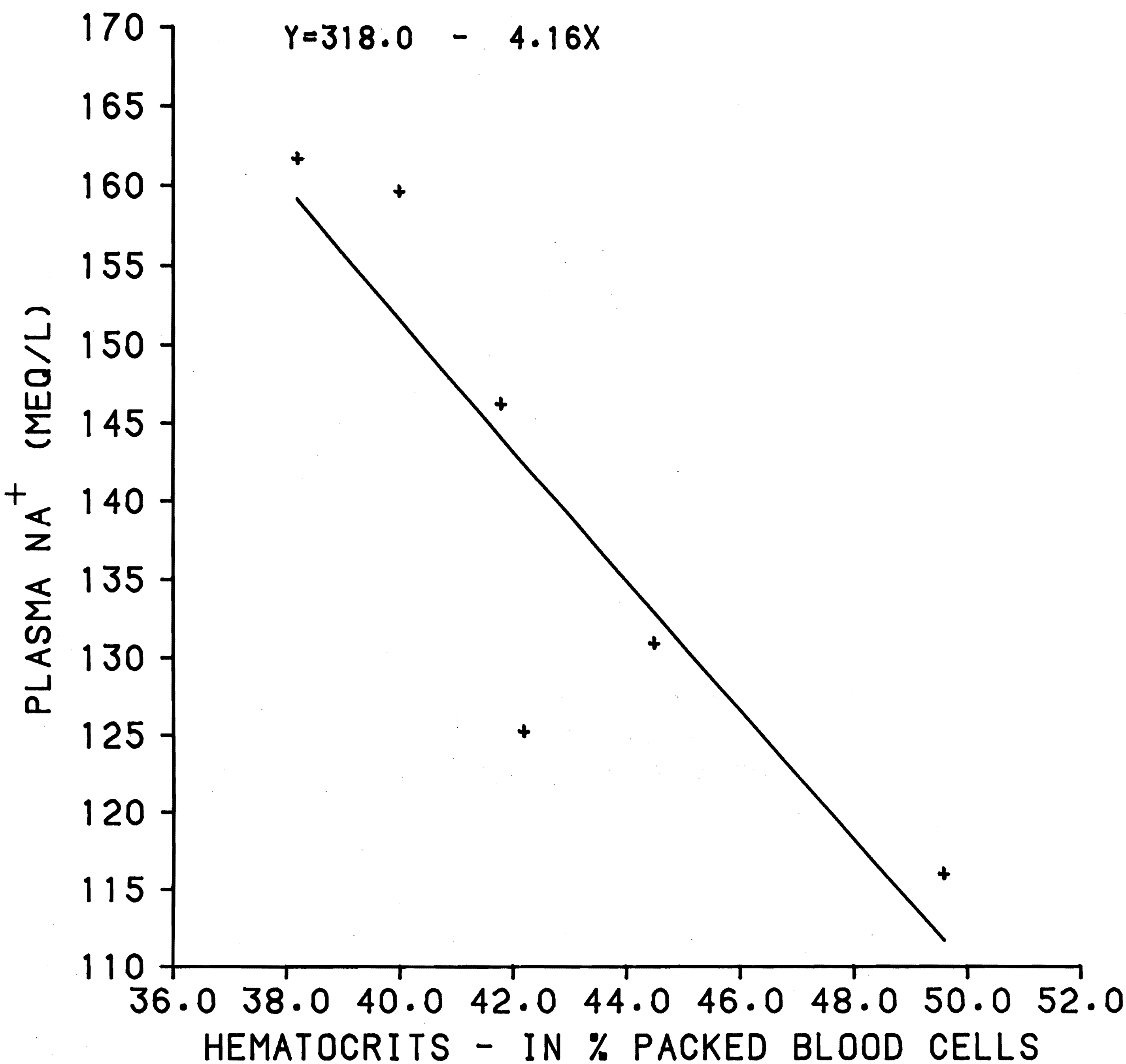


Figure 54.--Regression of mean plasma Na^+ values on mean hematocrits of Rapid River Hatchery spring chinook salmon during spring 1980. $r = -0.882$; $P < 0.02$.

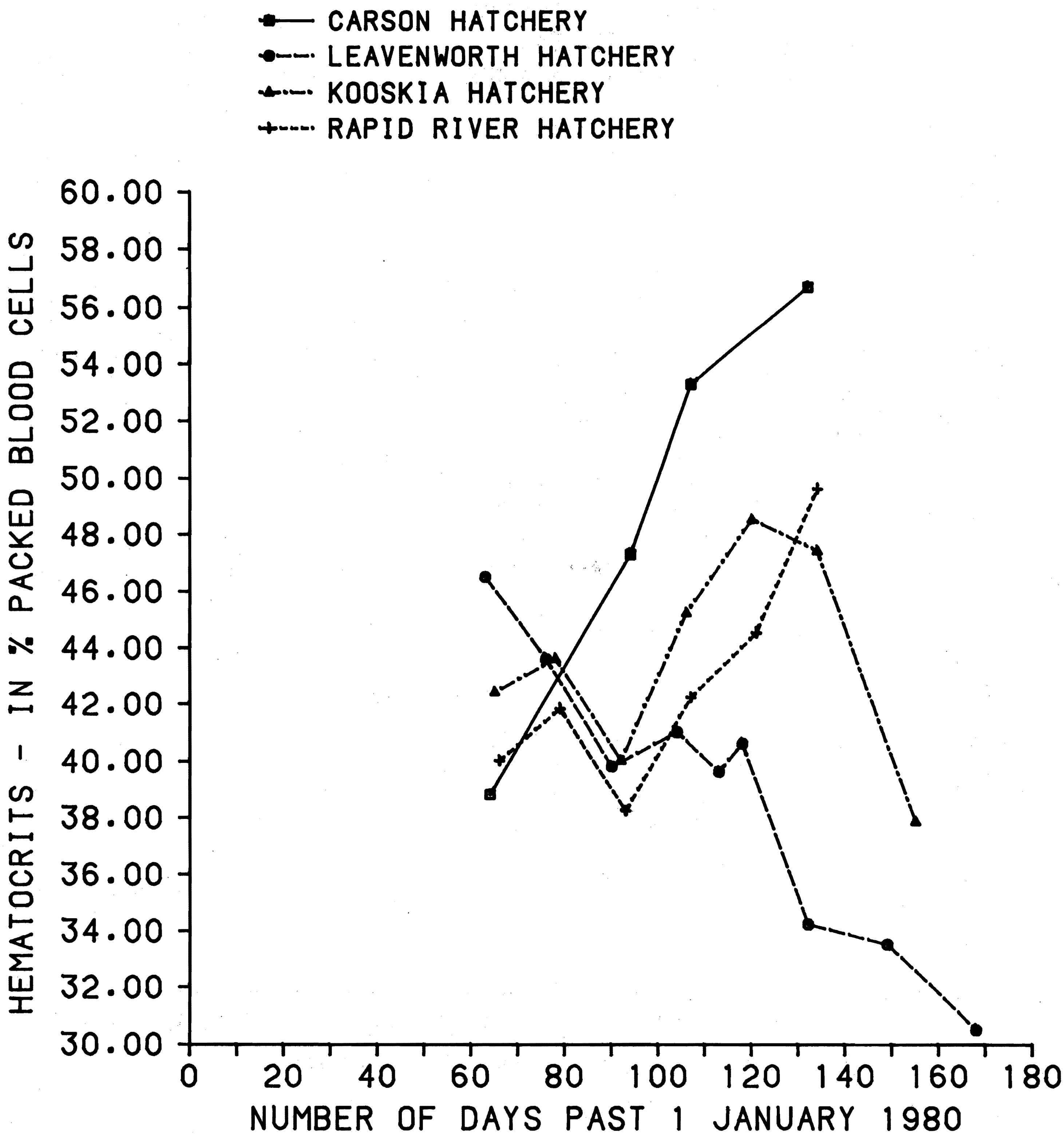


Figure 55.--Mean hematocrit values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

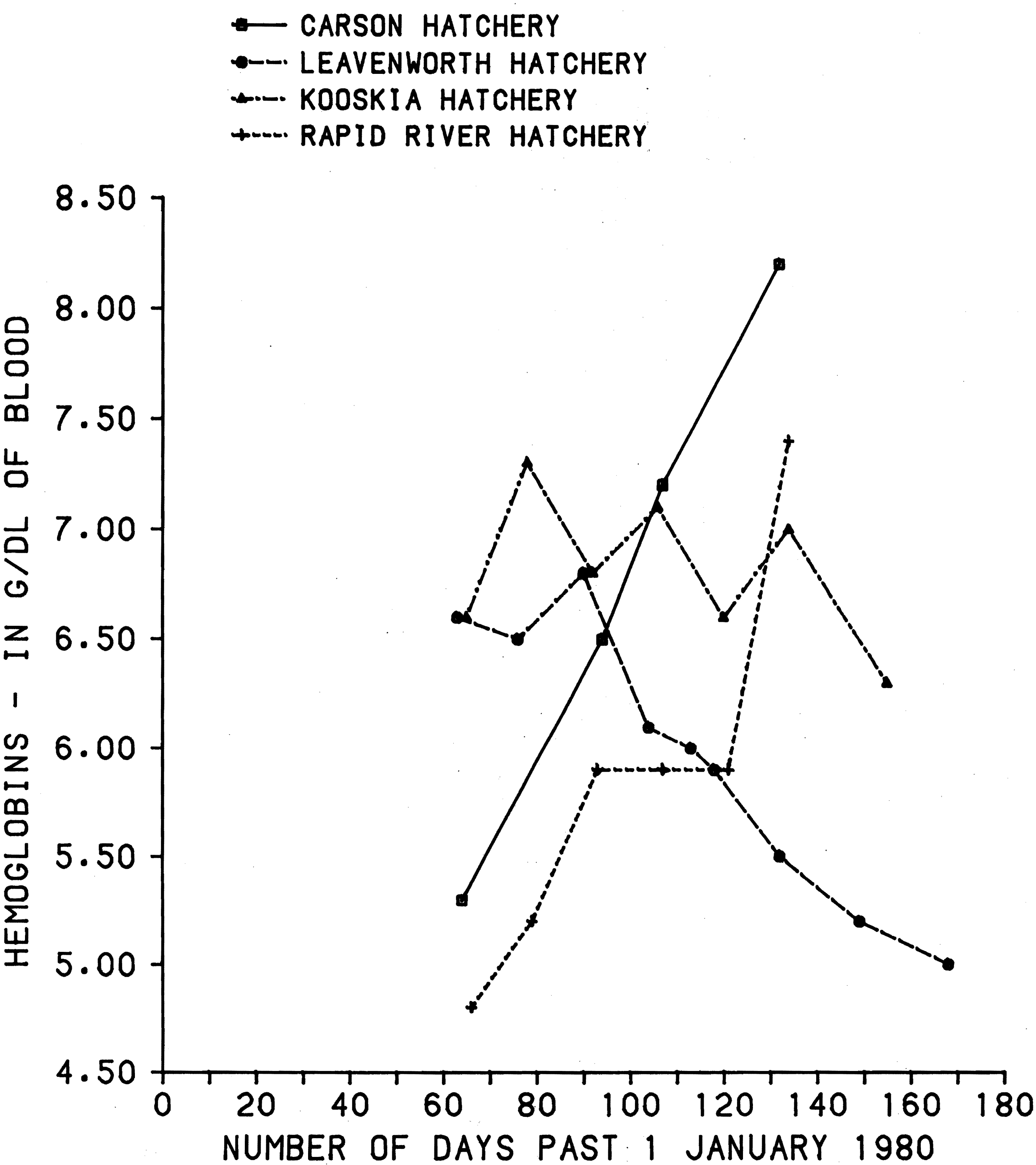


Figure 56.--Mean hemoglobin values of Carson, Leavenworth, and Kooskia NFH and Rapid River Hatchery spring chinook salmon during spring 1980.

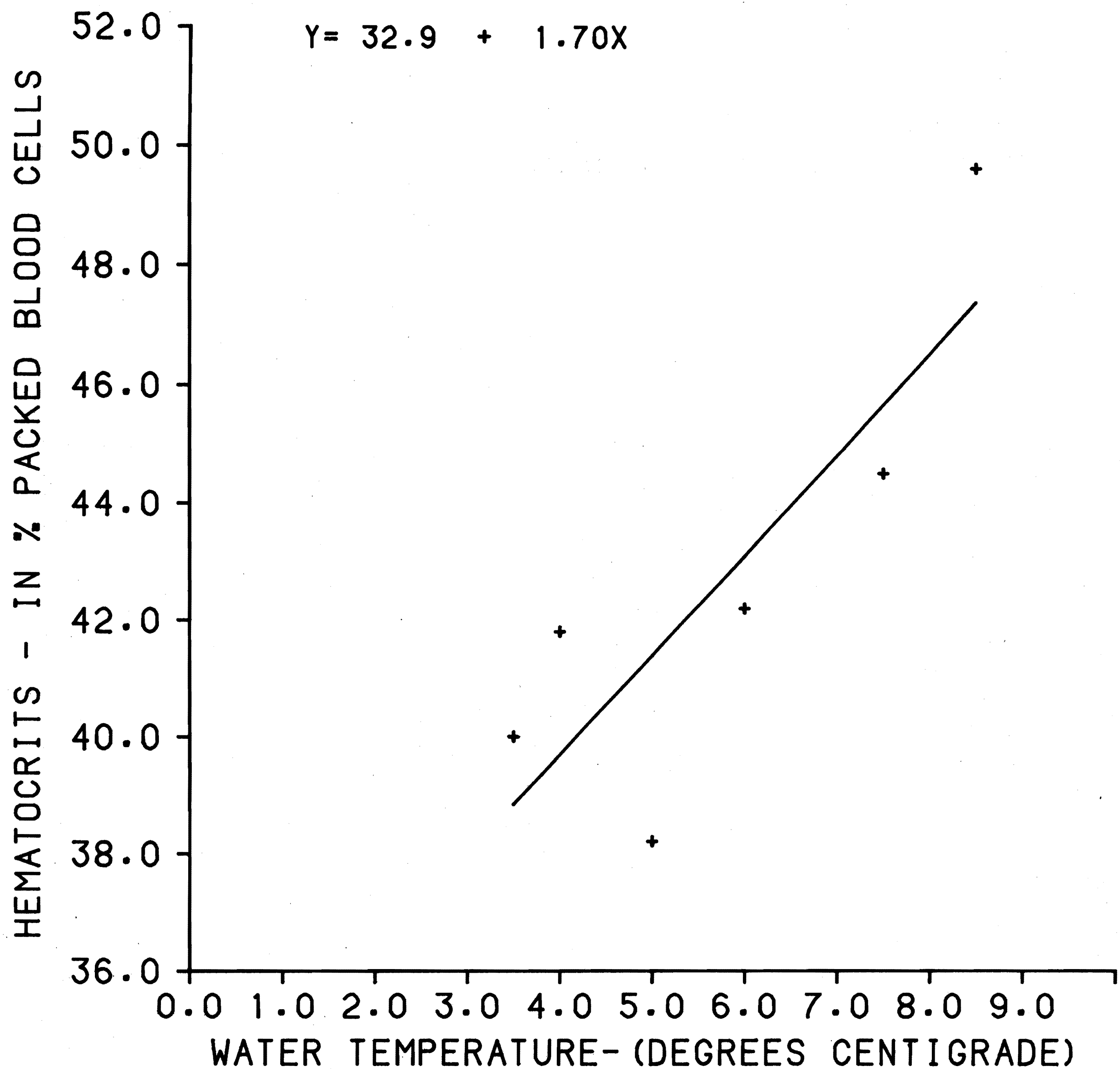


Figure 57.--Regression of mean hematocrit values of Rapid River Hatchery spring chinook salmon on Rapid River Hatchery water temperatures during spring 1980. $r = 0.840$; $P < 0.05$.

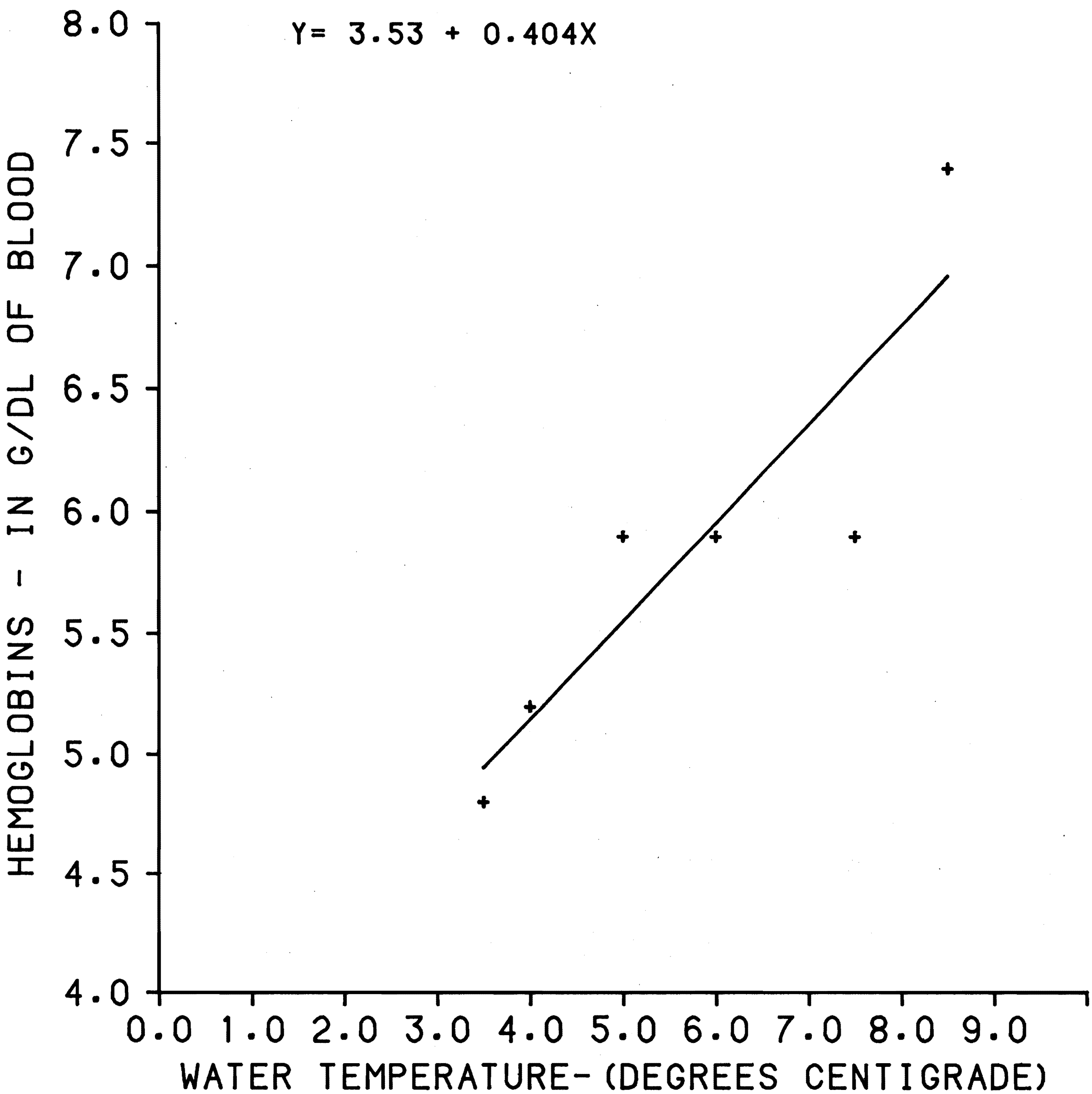


Figure 58.--Regression of mean hemoglobin values of Rapid River Hatchery spring chinook salmon on Rapid River Hatchery water temperatures during spring 1980. $r = 0.882$; $P < 0.02$.

Table 39.--Significant correlaiton coefficients for individual hematocrits and hemoglobins of Rapid River Hatchery spring chinook salmon during the 1980 sampling season.

Item	Period 1	2	3	4	5	6
Correlation coefficient	0.865	0.751	0.479	0.680	0.547	0.334
Degrees of freedom	58	58	58	55	53	50
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.02

The incidence of abnormally low and high hematocrit values was quite low during the migration period, and remained so until the last sampling period (Table 40).

Table 40.--Incidence of low and high hematocrit values in Rapid River Hatchery spring chinook salmon during the 1980 sampling season (expressed as precentage of the samples tested).

Item	Period 1	2	3	4	5	6
Hematocrits						
<30	5.0	3.3	5.0	5.2	5.5	0
≥55	0	0	0	5.2	9.0	25.5

Average mean cell hemoglobin concentrations (stress indicators) peaked prior to migration and declined throughout the migration periods (Figure 51).

On the basis of the information collected and evaluated, the general health index as expressed by hematological values examined was quite good throughout the season, and especially so at the time of emigration.

Table 41.--The incidence of BKD organisms in juvenile Rapid River Hatchery spring chinook salmon during the 1980 sampling season, as determined by IFAT-BKD.

	Percent of fish with BKD bacteria in the kidneys				
Period	Anterior kidney	Posterior kidney	Both kidneys	Totals	Comments on intensity[a]
#1 6 March	3.3	1.7	3.3	8.3	1.7 moderate 1.7 severe
#4 17 April	0	1.7	0	1.7	All light
#5 1 May	10.0	10.0	5.0	25.0	1.7 moderate

[a] Light = 1-9 organisms/150 microscopic fields
Moderate = 10-99 organisms/150 microscopic fields
Severe = $\bar{>}$ 100 organisms/150 microscopic fields

IFAT-BKD

Specimens of Rapid River Hatchery spring chinook salmon from the first, fourth, and fifth sampling periods of 198 were examined for the presence of BKD organisms by the IFAT (major migration was between the third and fourth periods).

The incidence of BKD was very low throughout the periods of pond sampling (Table 41), and the intensity of infection was classified primarily as light (1 to 9 BKD organisms/150 microscopic fields). Three fish (5%) were observed with gross BKD type lesions during the first sampling trip in March and none thereafter. This incidence averages 0.8% for the six sampling trips with 95% confidence limits to a 1.8% incidence. The microscopically (IFAT-BKD) observed frequency of 1.7% during the major migration (Table 41) has an upper 95% confidence limit of 5.0%.

The results of detection methods indicate that treatment of the adult parent stock and eggs with erythromycin phosphate was quite successful for the 1980 migrants. Increase in incidence in the "hold-over" fish may have been due to the stresses of confinement.

Histopathology

A summary of the pathological conditions observed is presented in Table 42. For comparative purposes, these data are further summarized with data from other hatcheries in Table 9.

Samples for a histopatholgical profile were collected during the first three periods, the last (3 April) representing the beginning of migration. All samples came from ponds, none were from the confined holding area.

Lesions of the gills and olfactory sac were consistently high throughout the sampling periods, and there was a persistently high

Table 42.--Pathological conditions observed in 1980 Rapid River Hatchery spring chinook salmon and their percentage of incidence.[a/]

Organ and pathology	Incidence(%) Period 1 (severity)[b/]				Period 2 (severity)				Period 3 (severity)			
	I	II	III	total	I	II	III	total	I	II	III	total
Eye												
skeletal muscle lesions	43.3	0	0	43.3	55.0	0	0	55.0	59.3	0	0	59.3
retrobulbar fat lesions	0	0	0	0	1.7	0	0	1.7	0	0	0	0
Gills												
increased numbers of lymphocytes	83.3	13.3	0	96.6	63.3	8.3	0	71.6	78.0	13.6	0	91.5
epithelial cell formation	31.7	65.0	1.7	98.4	58.3	23.3	0	81.6	50.9	47.5	0	98.4
vascular telangiectasis of secondary lamellae	3.3	0	0	3.3	3.3	0	0	3.3	8.5	0	0	8.5
Olfactory sac												
focal mononuclear cell infiltration	76.7	6.7	0	83.40	76.7	13.3	0	90.0	0	79.7	17.0	96.7

a/ Brain tissue was processed and examined for all specimens and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

proportion of fish with lesions of intermediate severity. However, summarized comparative data presented in Table 9 indicate that the severity and incidence were only slightly higher than those of other spring chinook salmon stocks in the study.

Summary

Serial sampling of Rapid River Hatchery spring chinook salmon in 1980 indicated that general fish health was good from the early part of the season through release. The incidence of BKD as documented by indirect fluorescent antibody analysis of random samples was very low, probably indicating that the erythromycin phosphate program for the prevention of the vertical transmission of BKD was successful.

At release, Rapid River Hatchery fish were the largest of the four spring chinook salmon stocks in the study (Figure 46). Profiles of water temperatures were comparable to Kooskia and Leavenworth NFH (Figure 45), but the peak of the Na^{+}-K^{+} ATPase profile (Figure 47) occurred much earlier (this may have been due to the abrupt changes in environment). In contrast, the mean gill Na^{+}-K^{+} ATPase values of the Carson NFH stock (at Carson NFH) peaked at the same time as the Leavenworth and Kooskia NFH fish (Figure 47), in spite of a constant temperature at Carson NFH (Figure 45). Leavenworth and Kooskia NFH stocks are basically from Carson NFH transplants.

Average hematocrits and hemoglobins were comparable to those of Leavenworth NFH spring chinook salmon at release, but lower than Carson or Kooskia NFH fish (Figures 55 and 56). Profiles of average mean cell hemoglobin concentrations of all four spring chinook salmon hatchery stocks in the study indicate that they were all comparable, and that MCHC of the

Rapid River Hatchery stock were rapidly declining during outmigration (Figure 51). Mean plasma Na^+ values declined much more rapidly than those of the other spring chinook salmon stocks studied and were the lowest of the four at release (Figure 48). Mean plasma Cl^- values had the most abrupt changes of any of the stocks as evidenced by an extremely sharp decline during migration (Figure 49). A comparison of average plasma K^+ profiles for the spring chinook salmon stocks (Figure 50) indicates a declining curve throughout the season for Rapid River Hatchery fish, with the lowest points during outmigration. These lower stress indicator values (MCHC and plasma K^+) may be from the use of pond culture at Rapid River Hatchery.

All of the data indicate that Rapid River Hatchery stocks were in excellent condition at the time of outmigration.

RESULTS AND DISCUSSION OF FALL CHINOOK SALMON SURVEYS

Spring Creek National Fish Hatchery

General

Fall chinook salmon were sampled from a number of ponds at Spring Creek NFH in 1980, both for homing and smoltification studies. The analyzed data collected from both of these studies are presented in this report. Summarized data for fish released in the homing study are presented in Table 43. Sample sizes for these data are 60 fish/sampling period, and sample sizes for the data collected in other ponds are 30 fish. Individual weights were measured at Spring Creek NFH, and these data are also presented.

Figure 59 shows the average lengths of the fish sampled from homing study ponds and those sampled throughout the season from other ponds. There were no indications of differences in mean sizes of fish between ponds, and data collected from all normal production ponds typically represent homing study fish. Average weights of production pond fish are shown in Figure 60.

Gill Na^{+}-K^{+} ATPase

The gill Na^{+}-K^{+} ATPase profile in 1980 was characterized by a maximum decline at the release time of the homing study and hatchery evaluation fish (Figure 61). This was followed by a rapid increase to a maximum level that occurred about 40 days later in fish held past this release period (Figure 61). In contrast, the gill Na^{+}-K^{+} ATPase profile in 1979 indicated that the peak of activity occurred at normal release time in early May (Figure 62). Although the level of peak activity

Table 43.--Summary data for the spring (1980) sampling of Spring Creek Hatchery fall chinook used in homing tests, with means, standard deviations ( ), and ranges. Sample size = 60.

Item	Period 1	Period 2	Period 3
Date	10 March 1980	10 April 1980	8 May 1980
Days>Ja1[a]	70	100	128
Temp.-C°[b]		7.7 - 11.1°C	
Avg. Fk Ln[c]	74.2 (2.9)	79.2 (4.5)	92.1 (5.3)
(Range)	68-81	70-90	79-103
Avg. ATP Fk Ln[d]	73.2 (2.5)	80.3 (4.5)	93.0 (4.9)
(Range)	68-79	71-90	79-102
Avg. ATP[e]	18.2 (2.5)	16.2 (1.3)	9.8 (2.2)
(Range)	14.6-22.3	13.9-17.6	6.7-13.9
Avg. Hct[f]	48.5 (3.3)	55.2 (5.4)	55.1 (4.2)
(Range)	41-60	45-68	42-63
Avg. Hb[g]	7.0 (0.6)	8.4 (1.02)	8.8 (0.8)
(Range)	5.4-8.1	5.7-12.0	6.7-10.9
Avg. MCHC[h]	14.4 (1.5)	15.3 (2.4)	16.0 (1.4)
(Range)	11.0-19.3	9.0-21.0	13.5-21.0
Avg. Na^+[i]	---	133.6 (6.9)	142.9 (12.9)
(Range)		120-142	110-153
Avg. K^+[j]	---	4.4 (2.7)	5.1 (1.8)
(Range)		1.0-7.3	2.0-7.0
Avg. Cl^-[k]	---	118.5 (3.5)	125.7 (7.6)
(Range)		116-121	121-139
Na^+/Cl^-[l]	---	---	---

a/ Days>Ja1: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C.) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average fork lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. Atp: The average gill ATPase levels for that period. (Na^+-K^+ ATPase activity in μ moles Pi/mg protein/hour.)
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratios of the plasma sodium to chlorides for that period, averaged.

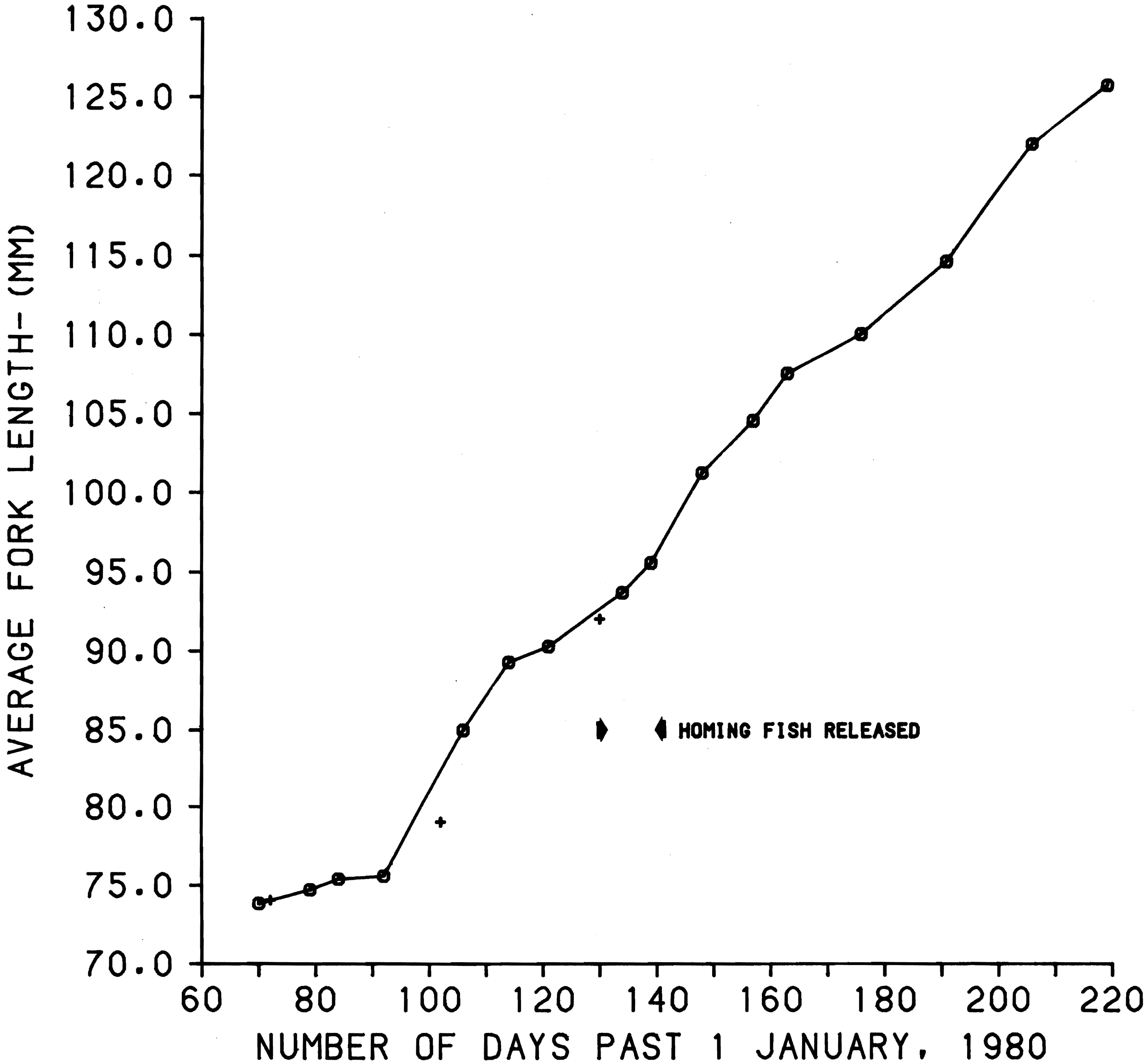


Figure 59.--Mean fork lengths of Spring Creek NFH fall chinook salmon during spring 1980. + = homing study fish (N = 60). ⊗ = fish from other ponds (N = 30).

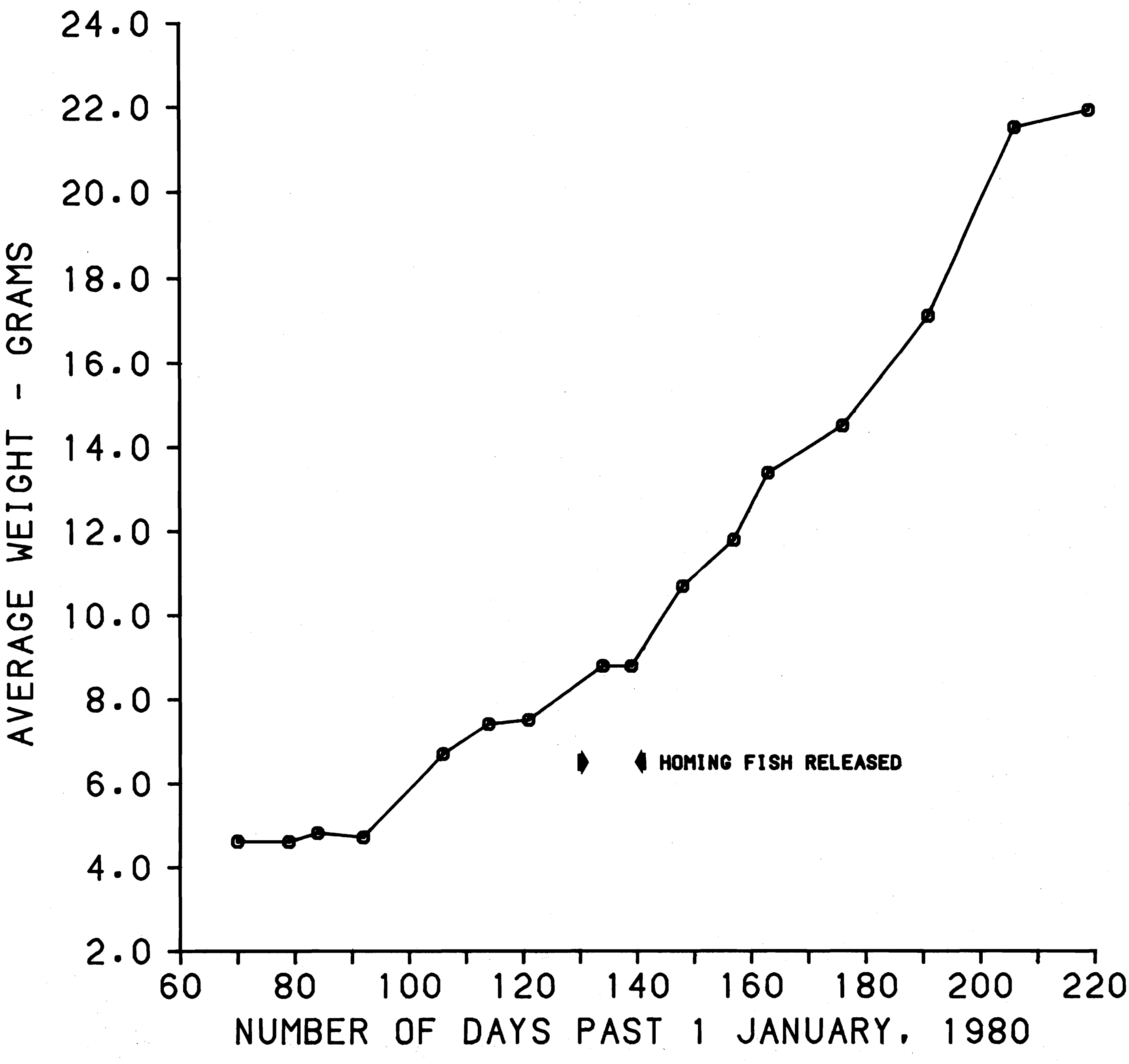


Figure 60.--Mean weights of Spring Creek NFH fall chinook salmon during spring 1980.

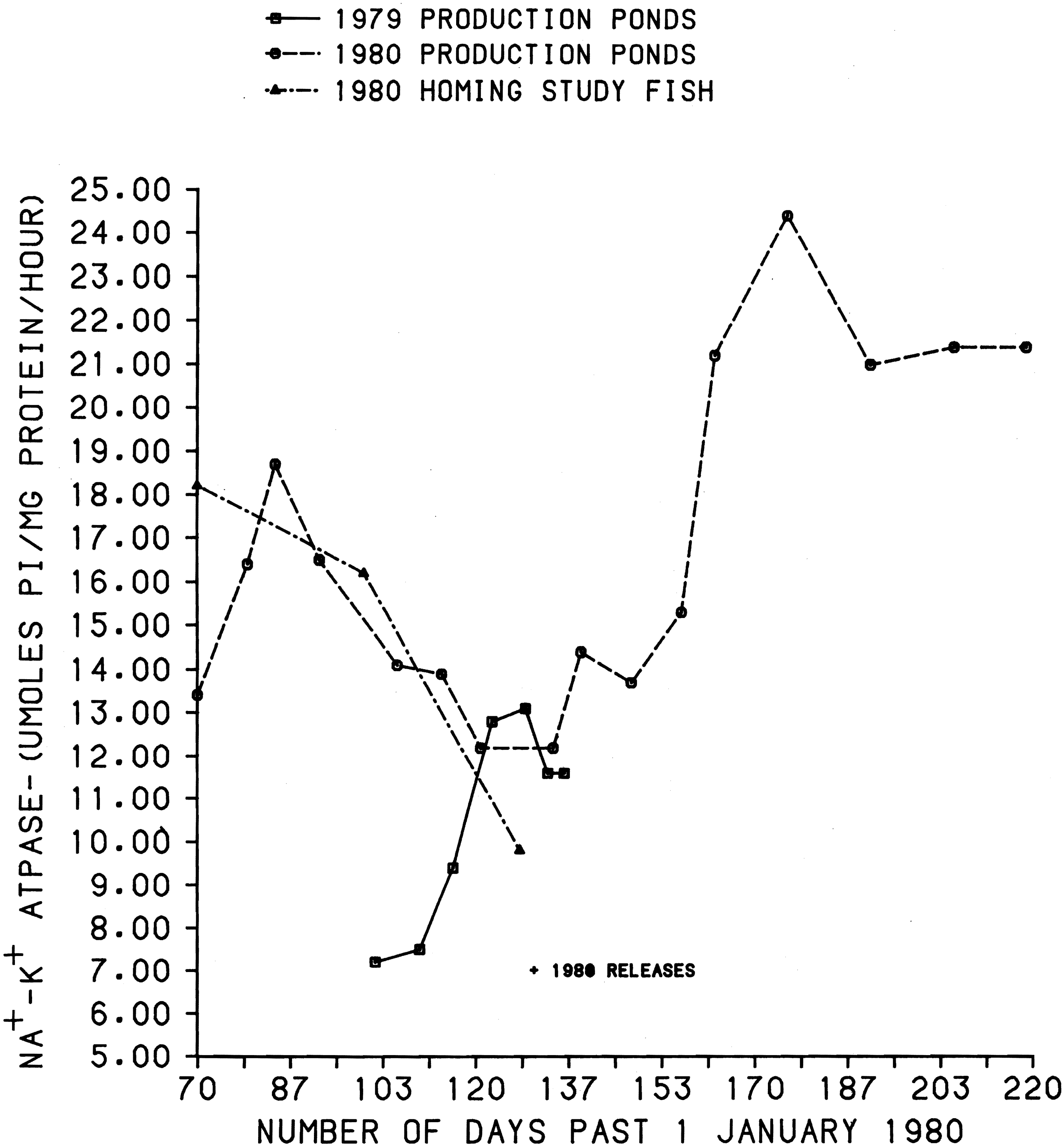


Figure 61.--A comparison of mean gill Na^{+}-K^{+} ATPase values of Spring Creek NFH fall chinook salmon during spring 1979 and spring 1980.

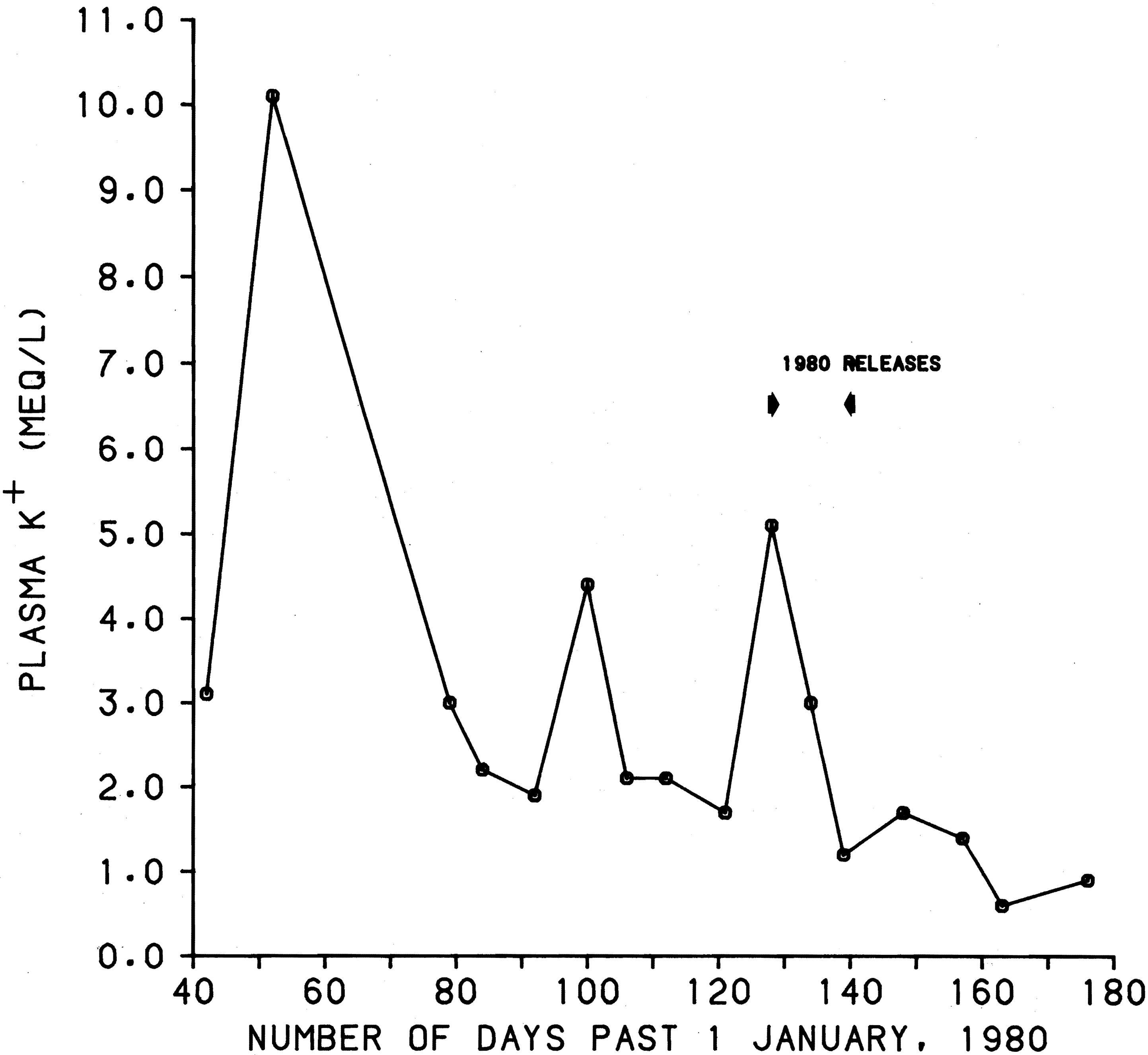


Figure 62.--Average plasma K^+ values for Spring Creek NFH fall chinook salmon during spring 1980.

was not as high in 1979 as in 1980, the rates of change were approximately the same. The difference in timing between the 1979 and 1980 peak activities is about 50 days (Figure 61), and this might influence survival.

Plasma Electrolytes

Mean plasma electrolytes as measured in homing study fish (Table 43) were generally within ranges reported for spring chinook salmon (Table 25), with the exception of K^+ values which were much higher than expected and could not be attributed to hemolysis. A profile of mean plasma K^+ as measured in production pond fish is presented in Figure 62. There are three periods of mean plasma K^+ levels that are sharply elevated above the norm, with a major peak occurring right at the time of release. This may be an indication of physiological stress at a critical time.

Mean plasma Na^+ values of production pond fish were variable early in the season and then generally rose in a cyclic pattern beginning in late March (Figure 63). There was a sharp increase in plasma Na^+ at the time of release, followed by a sharp decline at the end of the release period. Beginning in early May, these peak increases in plasma Na^+ occurred at regular 14-day intervals.

Mean plasma Cl^- values of the production pond fish were also quite variable (Figure 63). Plasma Cl^- values had declined to an intermediate low level at the time of release.

Mean plasma Na^+ and Cl^- levels in the Spring Creek NFH fall chinook salmon were generally in the same range as a typical yearling spring chinook salmon such as those from Leavenworth NFH. Differences in

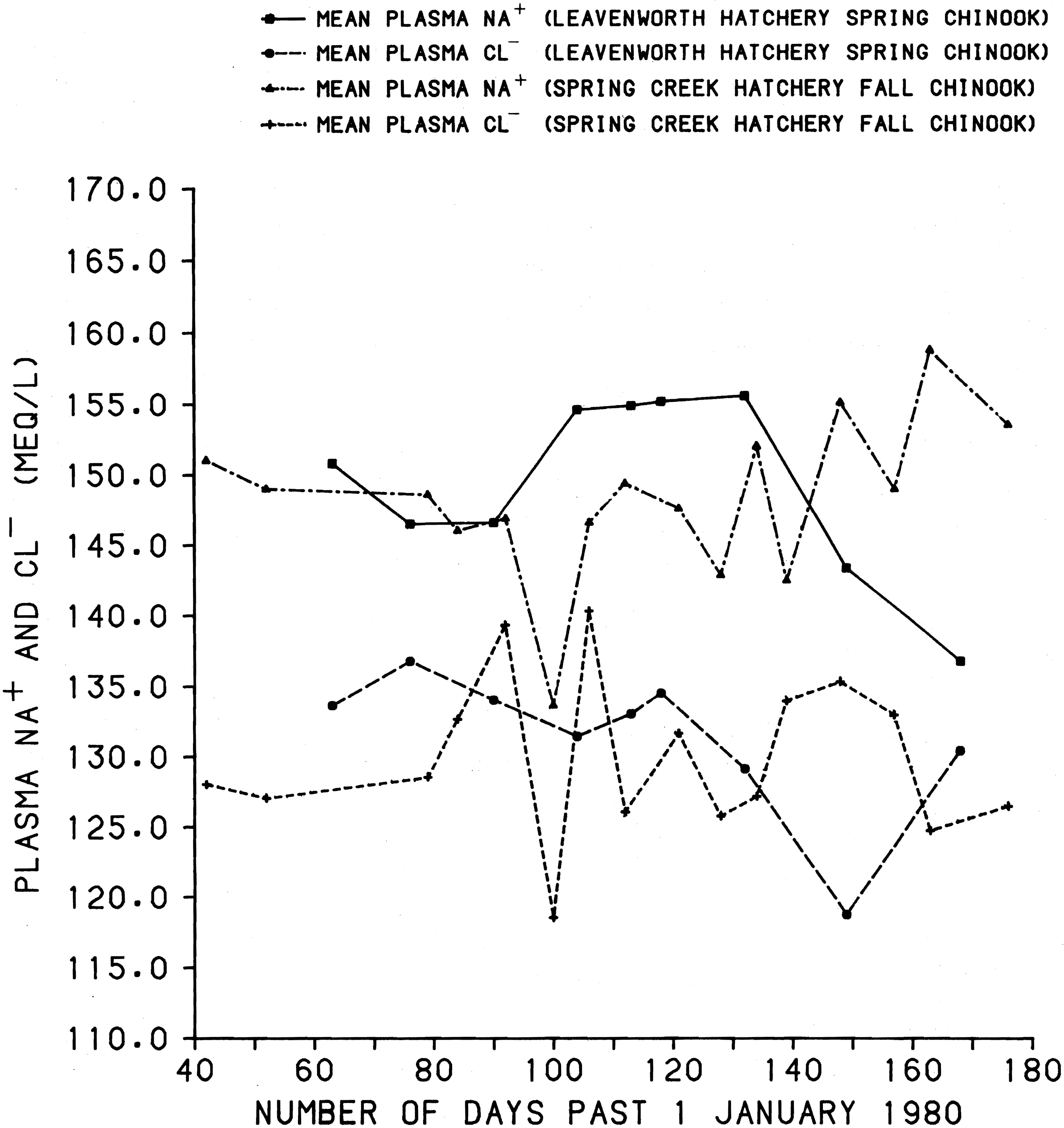


Figure 63.--Average plasma Na^+ and Cl^- values for Leavenworth NFH spring chinook salmon and Spring Creek NFH fall chinook salmon during spring 1980.

the profiles may reflect differences between yearling (spring chinook salmon) and 0-age (fall chinook salmon) fish (Figure 63).

Hematology

Blood was sampled only three times during the 1980 studies at Spring Creek NFH for hematological analysis. There were no individual samples with lower than normal values (Table 43). In the first period (10 March), 3.3% of the samples had hematocrits of 55% or more, and by 10 April, this figure had increased to 46.7%, and at release to 58.3%. There were no significant correlations between individual hematocrits and hemoglobins until the third (release) period ($r = 0.532$ for 53 d.f.; $P < 0.001$), which is unusual. Mean MCHC and hemoglobin values increased throughout the season (Table 43). There is no obvious explanation for the percentage of fish with high hematocrits, MCHCs, or hemoglobins in April-May, except that these values and the generally increasing mean plasma Na^+ (Figure 63) may indicate hemoconcentration resulting from a reduction in tissue water volume.

IFAT-BKD

Prepared specimens of Spring Creek NFH fall chinook salmon from the first, second, and third sampling periods of 1980 were examined for the presence of BKD organisms by the IFAT. However, data are only presented here for the second (10 April) period because of some technical difficulties in preparation of slides from the other periods.

BKD organisms were found in 23.7% of the anterior kidney smears, 11.9% of the posterior kidney smears, and 22.0% in both anterior and posterior kidney. The total number positive for BKD was 57.6%.

Infected fish were classified as 73.6% light (1.9 organisms/150 m.f.), and 26.4% intermediate (10.99 organisms/150 m.f.) intensity. The upper limit was 35 organisms/150 m.f., and even though the incidence of infection was relatively high, no samples were observed with severe infections. Consequently, BKD may not be a serious problem in this stock.

Histopathology

A summary of the pathological conditions observed is presented in Table 44. For comparative purposes, these data are further summarized with data from the other hatcheries in Table 9.

The histopathological profile of Spring Creek NFH fall chinook salmon showed pronounced increases in numbers of lymphocytes in the gills and lesions of the olfactory sac by the time of release. Some of these high levels were comparable to spring chinook salmon 1 year older (i.e.,Carson NFH, Table 34).

Summary

Continued sampling of homing study and production fall chinook salmon from Spring Creek NFH in 1980 indicated a shift in the Na^{+}-K^{+} ATPase profile from previous years. Fish released in 1980 for the homing study were in the trough of a Na^{+}-K^{+} ATPase profile, which may have some effect on survival.

There was also evidence from hematological and plasma Na^{+} data that indicated a majority of the fish (at release) had excessively high hematocrits and plasma Na^{+} values, and may have been under some type of stress. Although we cannot quantify the effects of apparent deviations in these parameters from the norm, they should be taken into consideration.

Table 44.--Pathological conditions observed in 1980 Spring Creek Hatchery fall chinook and their percentage of incidence.[a]

Organ and pathology	Incidence (%) Period 1 (severity)[b]				Period 2 (severity)				Period 3 (severity)			
	I	II	III	total	I	II	III	total	I	II	III	total
Eye												
skeletal muscle lesions	18.3	0	0	18.3	6.8	0	0	6.8	21.7	0	0	21.7
Gills												
increased numbers of lymphocytes	65.0	10.0	0	75.0	25.4	1.7	0	27.1	56.7	43.3	0	100.0
vascular telangiectasis of secondary lamellae	8.3	0	0	8.3	22.0	5.1	0	27.1	1.7	0	0	1.7
Olfactory sac												
focal mononuclear cell infiltration	56.7	6.7	0	63.4	42.4	8.5	0	50.9	93.3	6.7	0	100.0

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (lease severe); II-intermediate; III-severe.

Big Creek Hatchery (ODFW)

General

Fall chinook salmon were sampled from the homing study fish in ponds at the Oregon Department of Fish and Wildlife's (ODFW) Big Creek Hatchery from 8 April until 13 May 1980, from a production pond on 22 May 1980, and from production fish held over in tanks from 23 May to 7 July 1980. Summarized data for fish released in the homing study are presented in Table 45. Sample sizes for these data are 60 fish/sampling period, and the sample sizes for data collected from fish in other ponds and tanks are 30 fish/sampling period. We were not able to collect adequate samples for plasma electrolyte analysis from the fish at Big Creek Hatchery. Water temperatures during the April-May period were quite stable (Table 45).

Although Spring Creek NFH and Big Creek Hatchery fall chinook salmon were released at approximately the same time, Spring Creek NFH fish were (on the average) over 10 mm longer. Mean sample weights of Big Creek Hatchery production fish were 6.8 g on 22 May 1980 (Table 45), and samples from production ponds at Spring Creek NFH averaged 9.0 g (Figure 60) at the same time.

Gill Na^{+}-K^{+} ATPase

The gill Na^{+}-K^{+} ATPase profile of the Big Creek Hatchery fall chinook salmon was characterized by rapidly increasing activity during the release period (Figure 64). Note that the shape of the profile of the Big Creek Hatchery fish is similar to that of fish from Spring Creek NFH (Figure 64) but begins to increase rapidly much earlier in the spring. Big Creek Hatchery fish were released at a favorable time of rapidly rising gill Na^{+}-K^{+} ATPase values.

Table 45.--Summary data for the spring (1980) sampling of Big Creek Hatchery fall chinook salmon used in the homing tests, with means, standard deviations (), and ranges. Sample size = 60.

Item	Period 1	Period 2	Period 3	Period 4
Date	7 Mar 80	21 Mar 80	4 Apr 80	10 Apr 80
Days>Jal[a/]	98	113	126	133
Temp. °C[b/]	9.3	10.3	9.4	9.4
Avg. Fk Ln[c/]	59.9	67.7	76.0	81.3
	(4.2)	(4.3)	(5.4)	(4.2)
(Range)	46-66	60-76	67-88	69-92
Avg. ATP Fk Ln[d/]	58.8	68.0	76.4	81.7
	(4.6)	(4.6)	(5.1)	(4.8)
(Range)	46-65	60-76	67-85	69-92
Avg. ATP[e/]	--	12.0	14.7	61.6
	--	(2.4)	(5.1)	(1.4)
(Range)	--	8.3-15.7	10.3-27.7	15.1-19.7
Avg. Hct[f/]	47.2	53.1	52.7	53.3
	(4.7)	(5.2)	(4.2)	(7.0)
(Range)	38-55	41-61	46-64	32-75
Avg. Hb[g/]	6.0	6.7	7.1	7.2
	(1.0)	(0.5)	(0.6)	(0.8)
(Range)	3.8-7.5	5.8-7.8	6.3-8.3	4.5-8.5
Avg. MCHC[h/]	--	12.7	13.6	13.7
	--	(1.3)	(0.8)	(2.1)
(Range)	--	11.1-15.4	11.6-15.3	7.6-20.5
Avg. Na^+[i/]	--	--	--	--
	--	--	--	--
(Range)	--	--	--	--
Avg. K^+[j/]	--	--	--	--
	--	--	--	--
(Range)	--	--	--	--
Avg. Cl^-[k/]	--	--	--	--
	--	--	--	--
(Range)	--	--	--	--
Na^+/Cl^-[l/]	--	--	--	--
	--	--	--	--
(Range)	--	--	--	--

a/ Days>Jal: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average for lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. ATP: The average gill ATPase levels for that period. (Na^+-K^+ activity in μ moles Pi/mg protein/hour.
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratio of the plasma sodium to chlorides for that period, averaged.

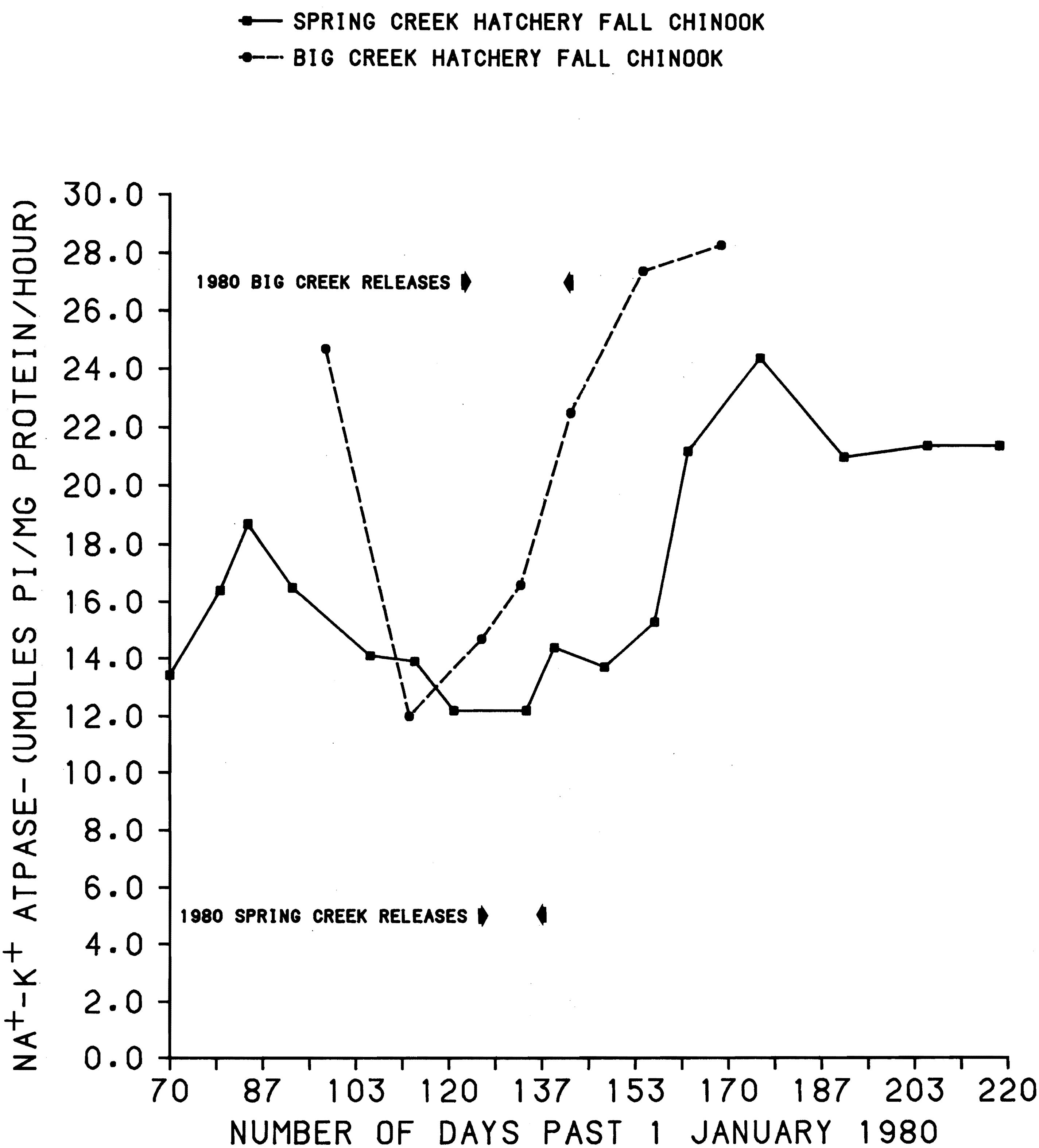


Figure 64.--A comparison of mean gill Na^{+}-K^{+} ATPase values of Big Creek and Spring Creek NFH fall chinook salmon during spring 1980.

Gill Na^+-K^+ ATPase values could only be significantly correlated with fork lengths in the second sampling period ($P < 0.020$, $r = 0.717$, 8 d.f.) (Table 45).

Hematology

Blood was sampled four times during the studies at Big Creek Hatchery for hematological analysis. Early in the season, samples had to be pooled to obtain sufficient quantities for analysis as fish were small and volumes of blood that could be obtained were limited. There were no samples with lower than expected values (Table 45). The percentage of samples with hematocrits of 55% or more from the first through the fourth sampling periods were 10, 40, 30, and 40%, respectively. This was generally less than that of Spring Creek NFH fish, but still considerably high. The only significant correlations between hematocrits and hemoglobins occurred in the third period ($r = 0.745$ for 26 d.f.; $P < 0.001$). Mean hematocrits and hemoglobins increased sharply during April, and mean hemoglobin and MCHC values rose progressively throughout the season (Table 45). Whether high MCHC values in fall chinook salmon during the period of smoltification are related to smolting stresses or other factors is not possible to judge at this time.

IFAT-BKD

Prepared specimens of the Big Creek Hatchery fall chinook salmon from the second and fourth sampling periods of 1981 were examined for the presence of bacterial kidney disease organisms by the IFAT. Only 5% of the samples in either period were positive for BKD, and all of the intensities were classified as light.

Histopathology

A summary of the pathological conditions observed is presented in Table 46. For comparative purposes, these data are further summarized with data from other hatcheries in Table 9.

The histopathological profile of Big Creek Hatchery fish indicates that there were sharp increases in the frequency and severity of pathological conditions of the gills and olfactory sac by the third period, and that these conditions were not reduced by the fourth (release) period. In some cases these conditions were more severe than in Spring Creek Hatchery fish (Table 44).

Summary

The sampling of fall chinook salmon from Big Creek Hatchery in 1980 indicated that the fish were about 12% smaller than Spring Creek NFH fall chinook salmon at the time of release. Hematological data indicate a relatively high percentage of fish with high hematocrits at the time of release, which could indicate some degree of hemoconcentration. Levels of BKD were extremely low and light in intensity, which should indicate a low probability of mortality from this disease.

There were sharp increases in frequency and severity of certain pathological conditions of the gill and olfactory sac during the sampling season. Although we have no way, at present, of quantitatively relating these conditions to survival, this information should be kept in mind when assessing returning adults.

Table 46.--Pathological conditions observed in 1980 Big Creek Hatchery spring chinook salmon and their percentage of incidence. [a/]

	Incidence (%)															
	Period 1 (Severity)[b/]				Period 2 (Severity)				Period 3 (Severity)				Period 4 (Severity)			
Organ & pathology	I	II	III	Total	I	II	III	Total	I	II	III	Total	I	II	III	Total
Eye																
Skeletal muscle lesions	28.3	0	0	28.3	18.3	0	0	18.3	20.0	0	0	20.0	38.3	0	0	38.3
Gills																
Increased numbers of lymphocytes	13.3	3.3	0	16.6	33.3	3.3	0	36.6	63.3	33.3	0	96.6	66.7	23.3	0	90.0
Epithelial cell formation	45.0	16.6	0	61.6	8.3	1.7	0	10.0	48.3	40.0	3.3	91.6	36.7	58.3	0	95.0
Vascular telangiectasis of secondary lamellae	1.7	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0
Olfactory sac																
Focal mononuclear cell infiltration	1.7	0	0	1.7	58.3	1.7	0	60.0	46.7	26.7	0	73.4	71.7	23.3	0	95.0

[a/] Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

[b/] I-recognizable (least severe); II-intermediate; III-severe.

Hagerman National Fish Hatchery

It was not possible to collect extensive samples from fall chinook salmon reared at Hagerman NFH Hatchery because of distances involved. Samples were collected for gill Na^{+}-K^{+} ATPase analysis and shipped to the NMFS laboratory at Willard for analysis. Two groups of fish were transported from Hagerman NFH and released; one on 3 June and the other on 5 June 1980.

Mean fork lengths of fish sampled at the hatchery are shown in Figure 65. On the average, Hagerman NFH fall chinook salmon were 21% larger than Big Creek Hatchery fish and 10% larger than the Spring Creek NFH fish at the time of release.

A profile of gill Na^{+}-K^{+} ATPase activity is presented in Figure 66. Apparent peak activity was reached in early May and was sustained for at least 1 month. This activity level was the highest in fall chinook salmon studied and may be the result of warm water temperatures in the hatchery (approximately 14°C). The abrupt rise in Na^{+}-K^{+} ATPase activity indicates that the fish were probably physiologically prepared for emigration in early May and perhaps should have been released sooner.

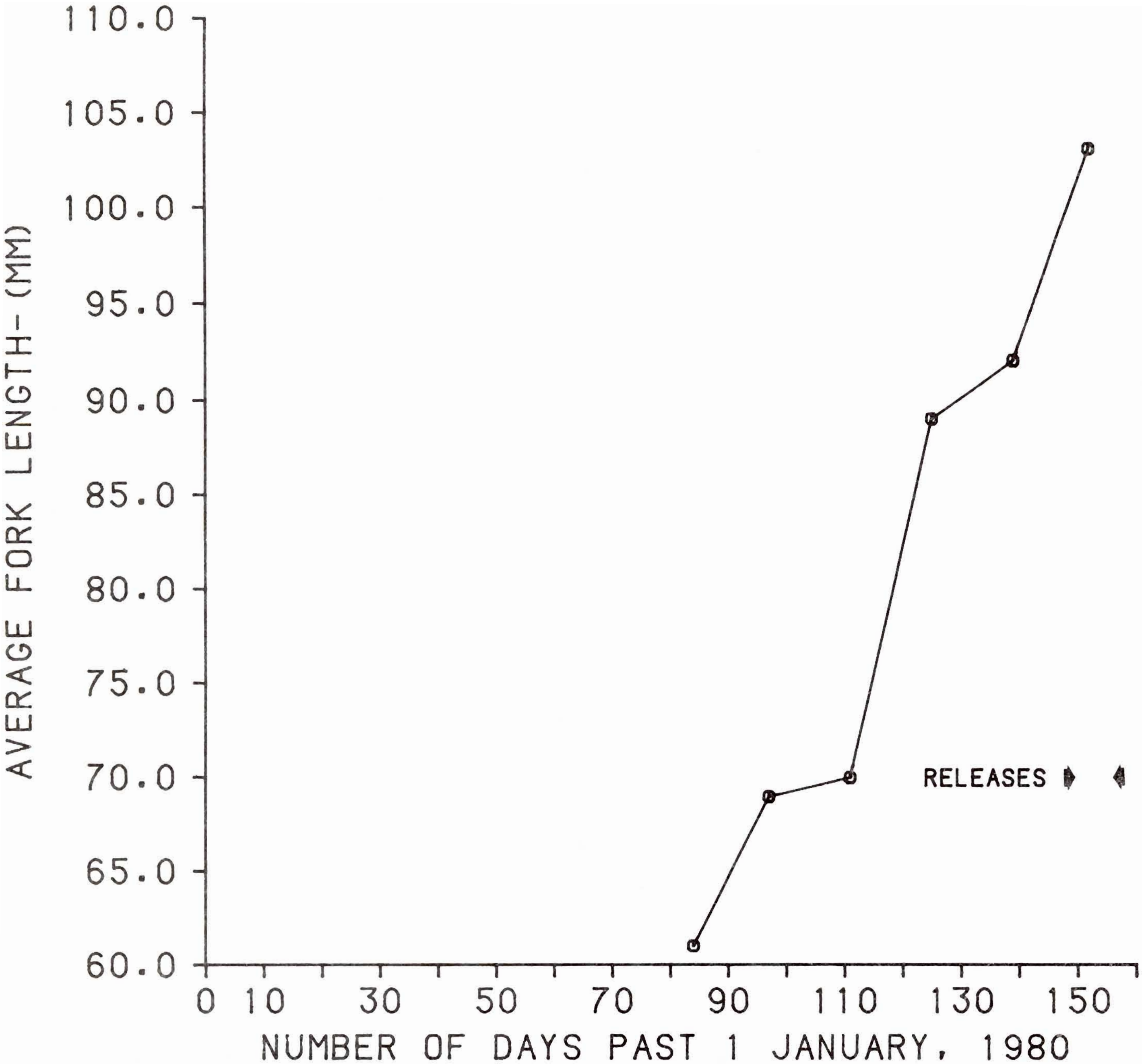


Figure 65.--Mean fork lengths of Hagerman NFH fall chinook salmon sampled during spring 1980 for gill Na^+-K^+ ATPase analysis.

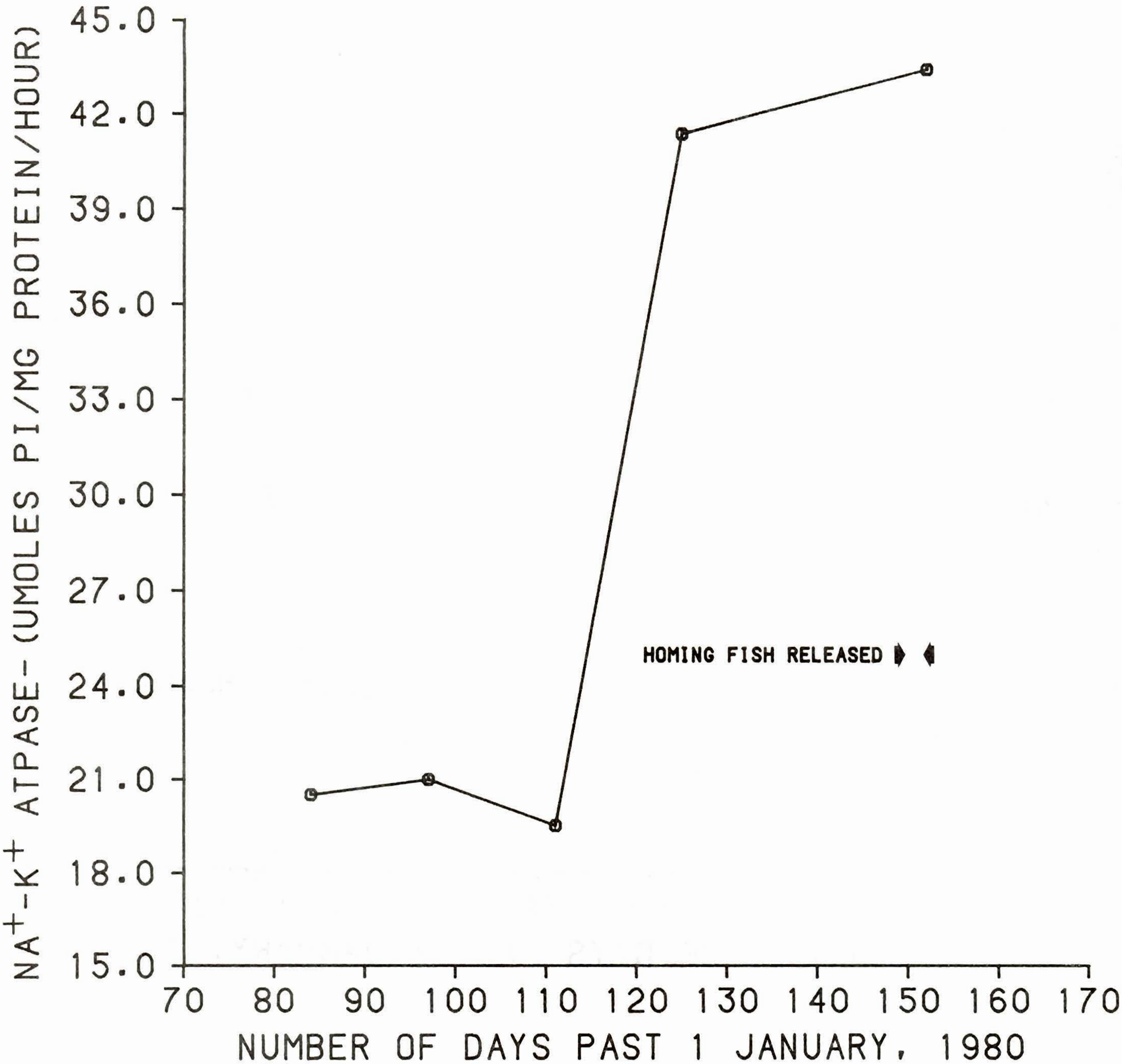


Figure 66.--Mean gill Na^{+}-K^{+} ATPase activity of Hagerman NFH fall chinook salmon sampled during spring 1980.

RESULTS AND DISCUSSION OF COHO SALMON SURVEY

Willard National Fish Hatchery

General

The only coho salmon that were involved in the 1980 homing studies were from the Willard NFH. Complete sampling was conducted at the Willard NFH on three occasions prior to release and these data are summarized in Table 47. Individual fork lengths, weights, and pooled gill samples for Na^{+}-K^{+} ATPase analysis were collected more frequently throughout the season, and representative samples of the population were held in tanks at the hatchery after the 24 May releases for post-release Na^{+}-K^{+} ATPase analysis. Figure 67 is a profile of water temperatures at the hatchery during the sampling periods. Note that temperatures were actually declining during the release period.

Figure 68 is a profile of average fork lengths of all fish measured during the 1980 sampling season at Willard NFH, and Figure 69 is a profile of average weights of fish measured during gill collecting sampling periods. Dips in mean length and weight are probably due to sampling errors.

Gill Na^{+}-K^{+} ATPase

The gill Na^{+}-K^{+} ATPase profile in 1980 was characterized by a rapid increase in activity followed by a similar decline. This peak was a pronounced height within several days of release (Figure 70). The 1980 profile was almost identical to that found in the sampling of Willard NFH coho salmon in 1978 (Figure 70), and on the basis of this information, the timing for release at peak activity was excellent in 1980.

Table 47.--Summary data for the spring (1980) sampling of Willard Hatchery coho salmon with means, standard deviations (), and ranges. Sample size = 60 (released 24 May 1980).

Item	Period 1	Period 2	Period 3
Date	5 Mar 80	2 Apr 80	20 May 80
Days>Ja1[a/]	65	92	141
Temp. °C[b/]	4.7	5.3	6.9
Avg. Fk Ln[c/]	104.0	114.9	126.1
	(10.0)	(11.2)	(8.0)
(Range)	78-120	92-149	103-140
Avg. ATP Fk Ln[d/]	102.9	116.3	126.0
	(10.2)	(10.3)	(7.5)
(Range)	82-118	92-142	126-138
Avg. ATP[e/]	8.8	10.5	17.5
	(1.8)	(1.9)	(5.5)
(Range)	5.3-11.2	6.8-13.4	10.3-25.5
Avg. Hct[f/]	40.3	46.3	57.6
	(5.2)	(7.6)	(11.6)
(Range)	29-57	29-76	24-89
Avg. Hb[g/]	5.1	6.6	7.0
	(0.7)	(1.5)	(1.4)
(Range)	3.2-7.2	4.0-12.0	2.3-9.3
Avg. MCHC[h/]	12.9	14.3	12.3
	(2.0)	(2.7)	(2.0)
(Range)	6.5-16.5	8.3-25.7	8.7-18.6
Avg. Na^+[i/]	161.4	153.2	151.3
	(16.7)	(6.7)	(15.9)
(Range)	116-178	141-162	96-198
Avg. K^+[j/]	2.92	5.30	7.09
	(0.87)	(2.92)	(2.66)
(Range)	1.28-4.28	1.92-13.50	2.58-13.50
Avg. Cl^-[k/]	129.1	131.6	138.4
	(13.8)	(6.8)	(12.7)
(Range)	98-151	112-141	111-171
Na^+/Cl^-[l/]	1.25	1.16	1.11
	(1.10)	(0.05)	(0.10)
(Range)	1.05-1.43	1.08-1.26	0.82-1.27

a/ Days>Ja1: The number of days post 1 January 1980 that the sampling period represents.
b/ Temp.-°C: Water temperature (in degrees C) measured for that period.
c/ Avg. Fk Ln: The average fork length (in millimeters) of all fish measured for that period.
d/ Avg. ATP Fk Ln: The average for lengths of fish used for the gill ATPase measurements for that period.
e/ Avg. ATP: The average gill ATPase levels for that period. (Na^+-K^+ activity in μ moles Pi/mg protein/hour.
f/ Avg. Hct: The average hematocrits for that period (% packed cells).
g/ Avg. Hb: The average hemoglobins for that period (in g/dl).
h/ Avg. MCHC: The mean corpuscular hemoglobin concentrations (Hb/Hct x 100) averaged for that period.
i/ Avg. Na^+: The average plasma sodium for that period (in meq/l).
j/ Avg. K^+: The average plasma potassium for that period (in meq/l).
k/ Avg. Cl^-: The average plasma chloride for that period (in meq/l).
l/ Na^+/Cl^-: The ratio of the plasma sodium to chlorides for that period, averaged.

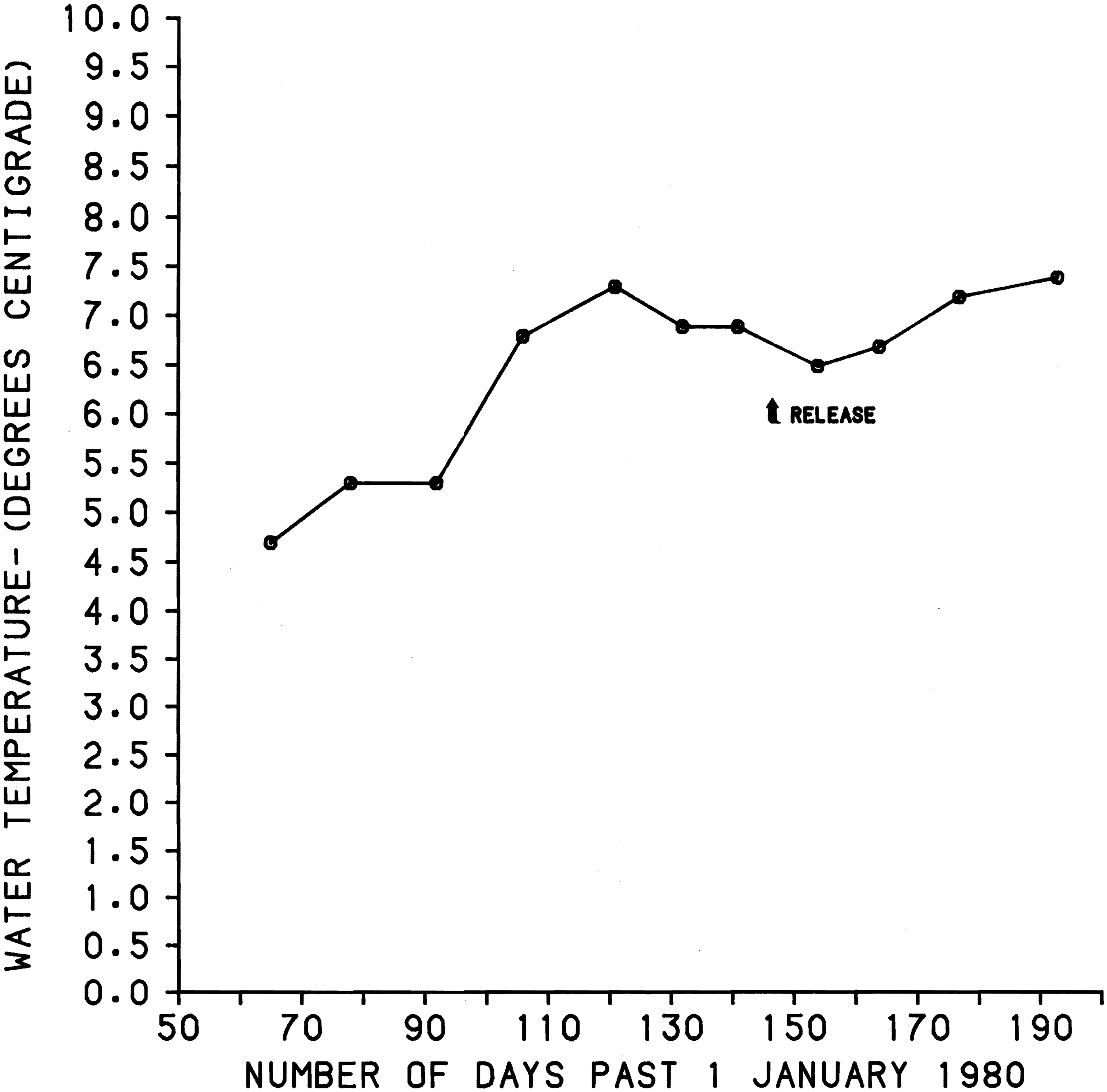


Figure 67.--Water temperatures at Willard NFH during spring 1980.

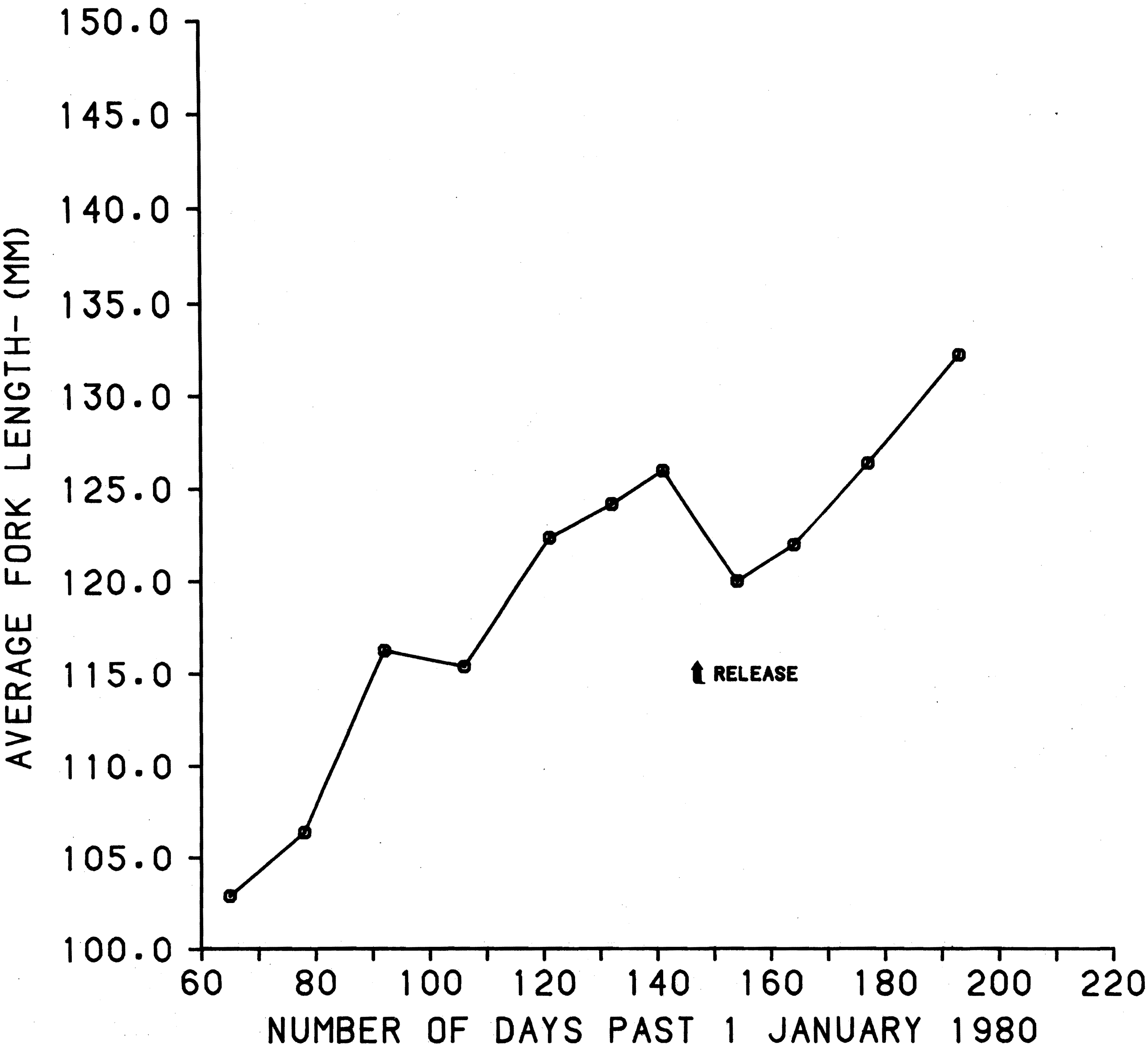


Figure 68.--Mean fork lengths of Willard NFH coho salmon sampled during spring 1980.

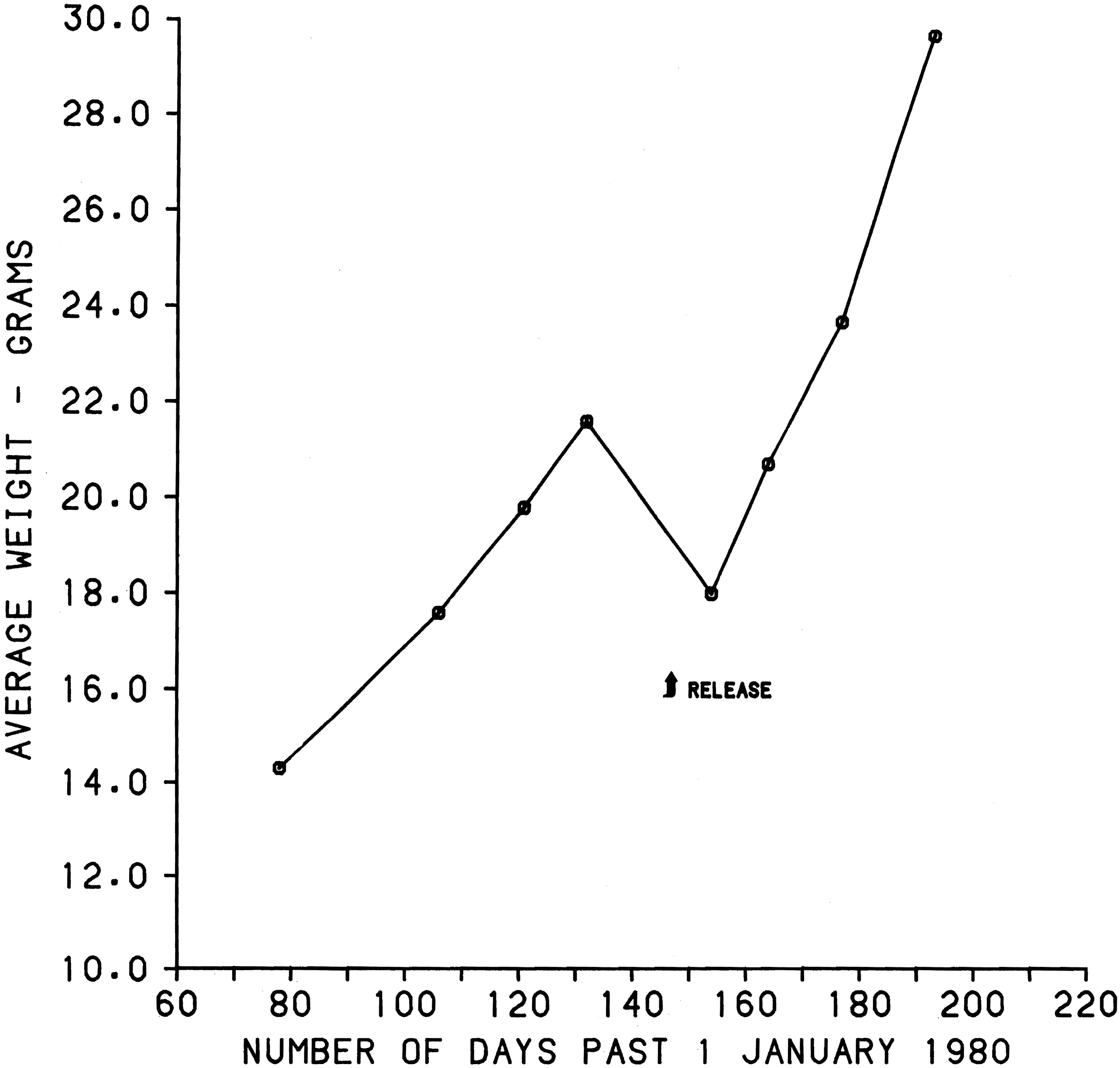


Figure 69.--Mean weights of Willard NFH coho salmon sampled during spring 1980.

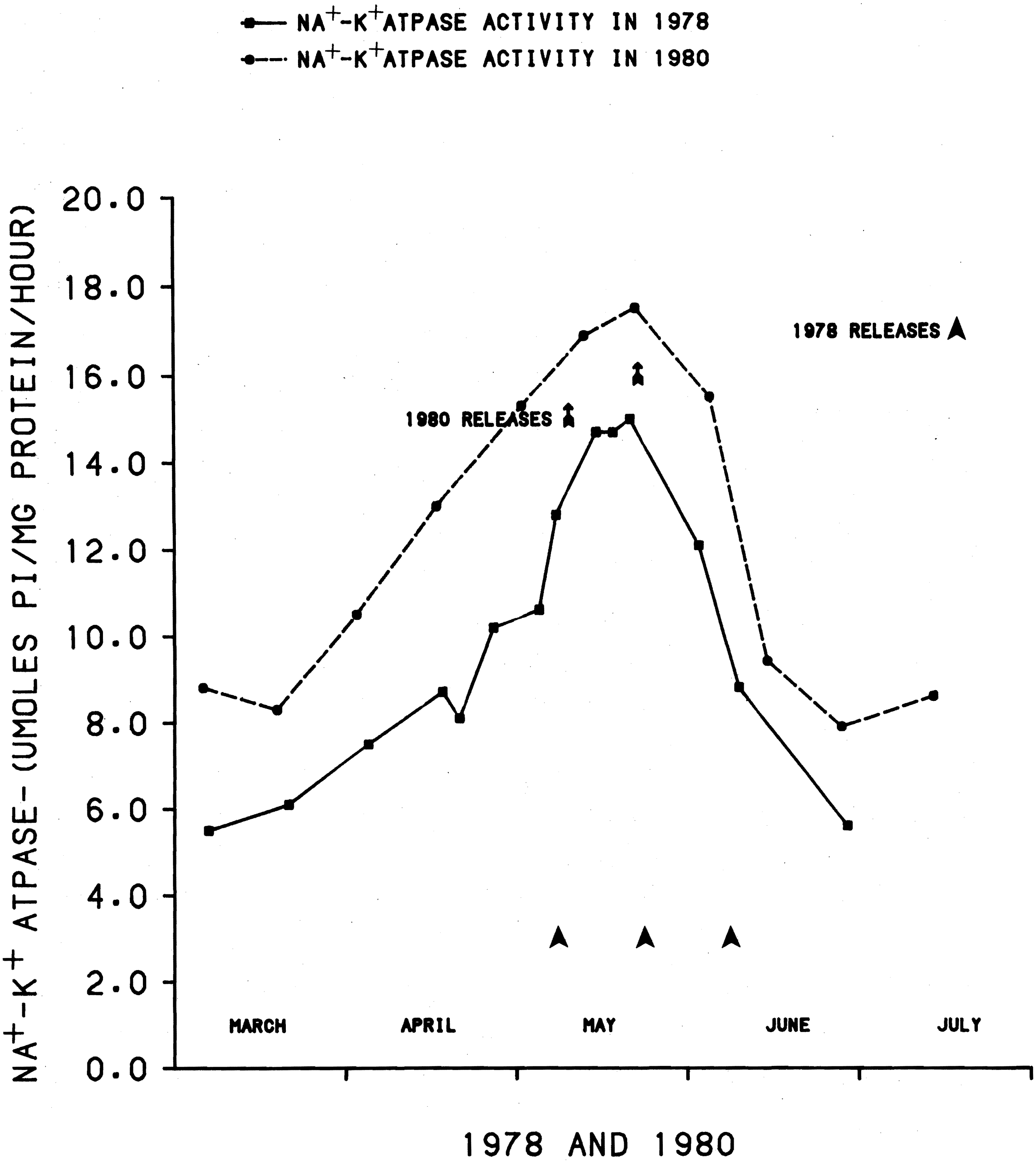


Figure 70.--Mean gill Na^{+}-K^{+} ATPase activity of Willard NFH coho salmon sampled during spring 1978 and 1980.

There were no significant correlations between pooled sample fork lengths and Na^+-K^+ ATPase in any of the sample periods. There was a positive correlation ($r = 0.739$; $P < 0.020$ for 8 d.f.) between gill Na^+-K^+ ATPase and pooled plasma Cl^- in the 5 March sampling period, which is in contrast to the theory that plasma Cl^- declines with the onset of smoltification. There was a negative correlation ($r = 0.847$; $P < 0.005$ for 6 d.f.) between gill Na^+-K^+ ATPase and pooled plasma K^+ in the 20 May sampling period, and a positive correlation ($r = 0.667$; $P < 0.05$ for 7 d.f.) between gill Na^+-K^+ ATPase and pooled hematocrits in the 20 May period. There do not appear to be any consistencies with these correlations, and therefore they may not be relevant.

In Figure 71, the percentage of samples with Na^+-K^+ ATPase values $\geq$ 15 begins to rise rapidly by mid-April (30%). This percentage increases to over 60 by the time of release (mid-May) and is sustained through early June. Before mid-April, none of the fish had Na^+-K^+ ATPase values over 15 u moles Pi/mg protein/hour. On the basis of this information, it would appear that 50-60% of the fish were smolting at release.

Plasma Electrolytes

Miles and Smith (1968) reported on plasma electrolytes in hatchery coho salmon. Spring samples of fish in fresh water averaging 12.5 g were as follows:

	Mean (mEq/l)	Range (mEq/l)
Na^+	146.7	130.0-168.0
Cl^-	117.3	90.0-132.6
K^+	8.6	1.8- 19.0

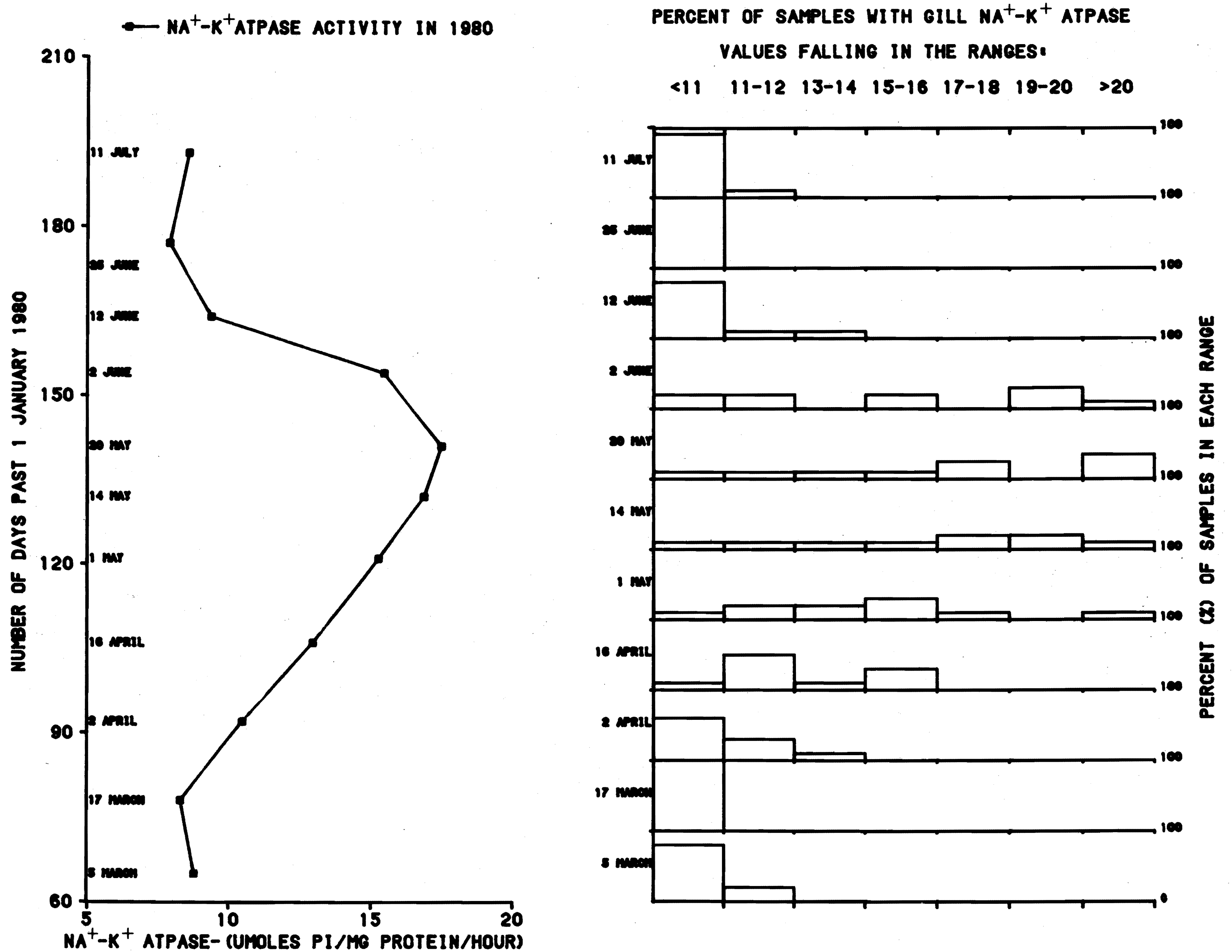


Figure 71.--Frequency of gill Na^{+}-K^{+} ATPase values of Willard NFH coho salmon sampled throughout spring 1980. A profile of the mean values is shown for reference.

Our own studies of Columbia River Hatchery coho salmon in 1978 resulted in the following ranges of mean values for plasma electrolytes:

	mEq 1
Na^+	140.8 - 170.0
Cl^-	113.4 - 140.8
K^+	5.7 - 8.4

Mean plasma electrolyte values (Table 47) were within the expected values or the values found in Columbia River hatchery coho salmon in 1978. Both minimum and maximum plasma Na^+ values were beyond those reported by Miles and Smith (1968), as were the maximum plasma Cl^- values. Apparently plasma K^+ values are normally higher in coho salmon than in chinook salmon.

Profiles of mean plasma electrolyte values for the three major sampling periods are shown in Figure 72, and compared here with mean gill Na^+-K^+ ATPase values collected at the same times. There is actually a significant positive correlation ($r = 0.997$; $P < 0.05$ for 1 d.f.) between the mean Na^+-K^+ ATPase and the mean plasma Cl^- values. But, this trend of increasing plasma Cl^- and decreasing plasma Na^+ as the fish approach smolting would not appear to be typical. The gradual increases in plasma K^+ values could be expected with increased stresses from growth and the onset of smolting. There was no evidence of sharply elevated plasma K^+ values at the time of release that would indicate serious stress problems. The median value (6.4 mEq/1) was below the mean (7.1 mEq/1), and only 12% of the samples had values of 10 mEq/1 or higher. As mentioned previously, there was a highly significant negative correlation between the gill Na^+-K+ ATPase and plasma K^+ at the time of release, and this correlation is shown in Figure 73. If the high Na^+-K^+ ATPase

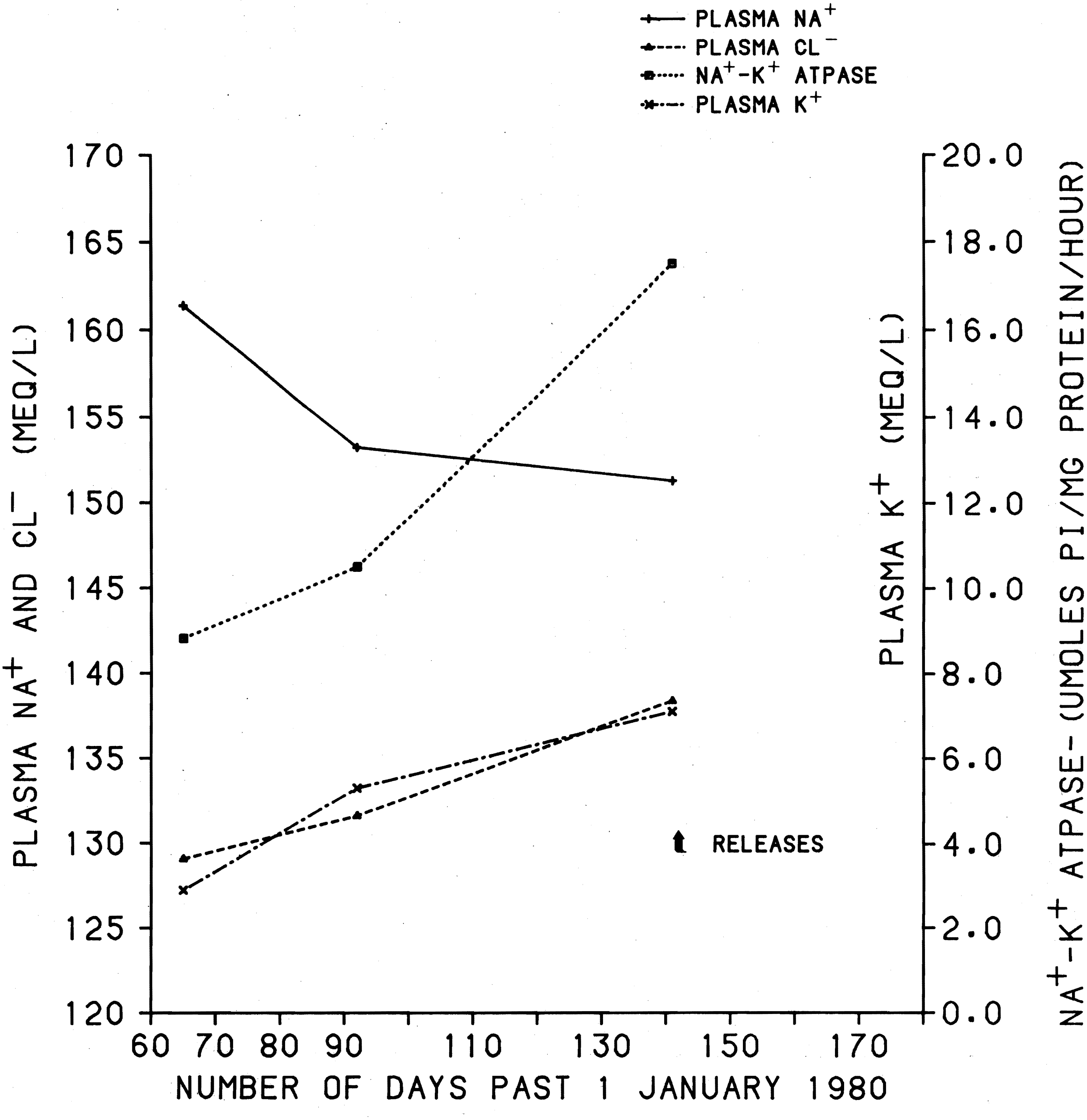


Figure 72.--Mean plasma Na^+, Cl^-, and K^+ values in the Willard NFH coho salmon during spring 1980 are compared with mean gill Na^+-K^+ ATPase activity.

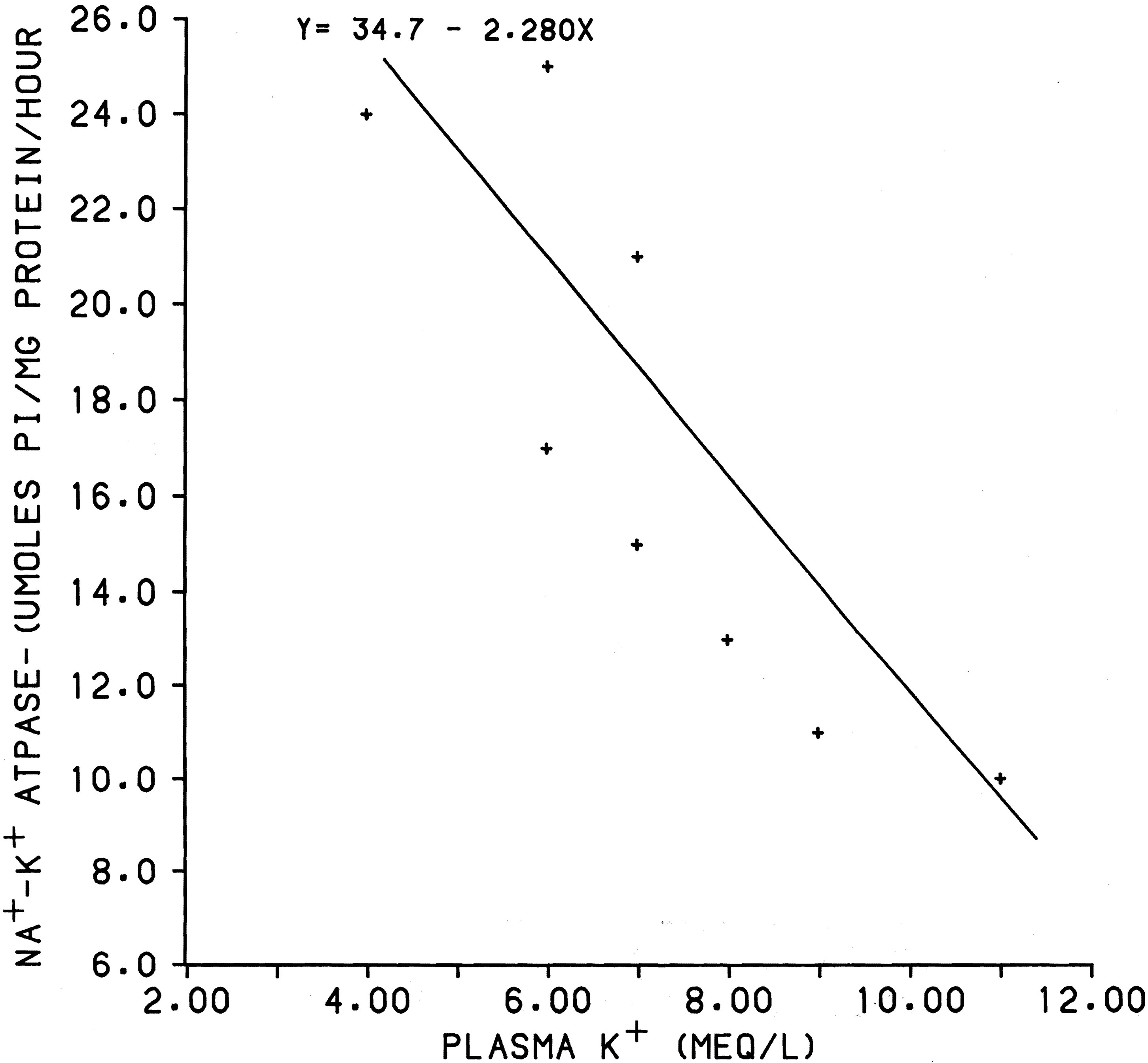


Figure 73.--Regression of pooled gill Na^+-K^+ ATPase activity on pooled plasma K^+ values of Willard NFH coho salmon at the time of release (24 May 1980). $r = -0.847$; $P < 0.005$ (for 6 d.f.).

values are indicative of true smolting activity, any stresses related to this are not indicated by classic plasma K^+ responses.

Hematology

Wedemeyer and Chatterton (1971) list normal expected values (for coho salmon) in fresh water of 32.5 to 52.5% for hematocrits and 6.5 to 9.9 g/100 ml of blood for hemoglobins. Summarized data for the Willard NFH coho salmon in 1980 are presented in Table 47.

In 1978, there were three marked release groups of Willard NFH coho salmon. The first two were within $\pm$ 6 days of the 1980 release group.

Figure 74 compares hemoglobin profiles of 1978 and 1980 Willard NFH coho salmon from our samplings. Note that at the times of release, means and standard deviations for both years were quite similar. However, when we compare profiles of hematocrits, there was a substantial difference (Figure 75), and mean values at the time of release in 1980 were 26% higher than peak mean value in 1978. Some of this differential may be due to transport stresses in 1978. We indicated that between 9 and 18% of the fish in the first two release samples in 1978 had hematocrits above the expected high values published by Wedemeyer and Chatterton (1971). In 1980, 68% of the samples had hematocrits above the expected value and even the mean was above the expected high. We also indicated (in 1978) that between 6 and 10% of the first two release groups had hematocrits below the expected low value. In 1980, only 3.4% of the fish had low hematocrits at release, which indicates that only a small number of fish could be classed as having a low health index. This large proportion of fish with high hematocrits at release time may be an indication of extreme water loss associated with smoltification. As was previously mentioned, there was a significant

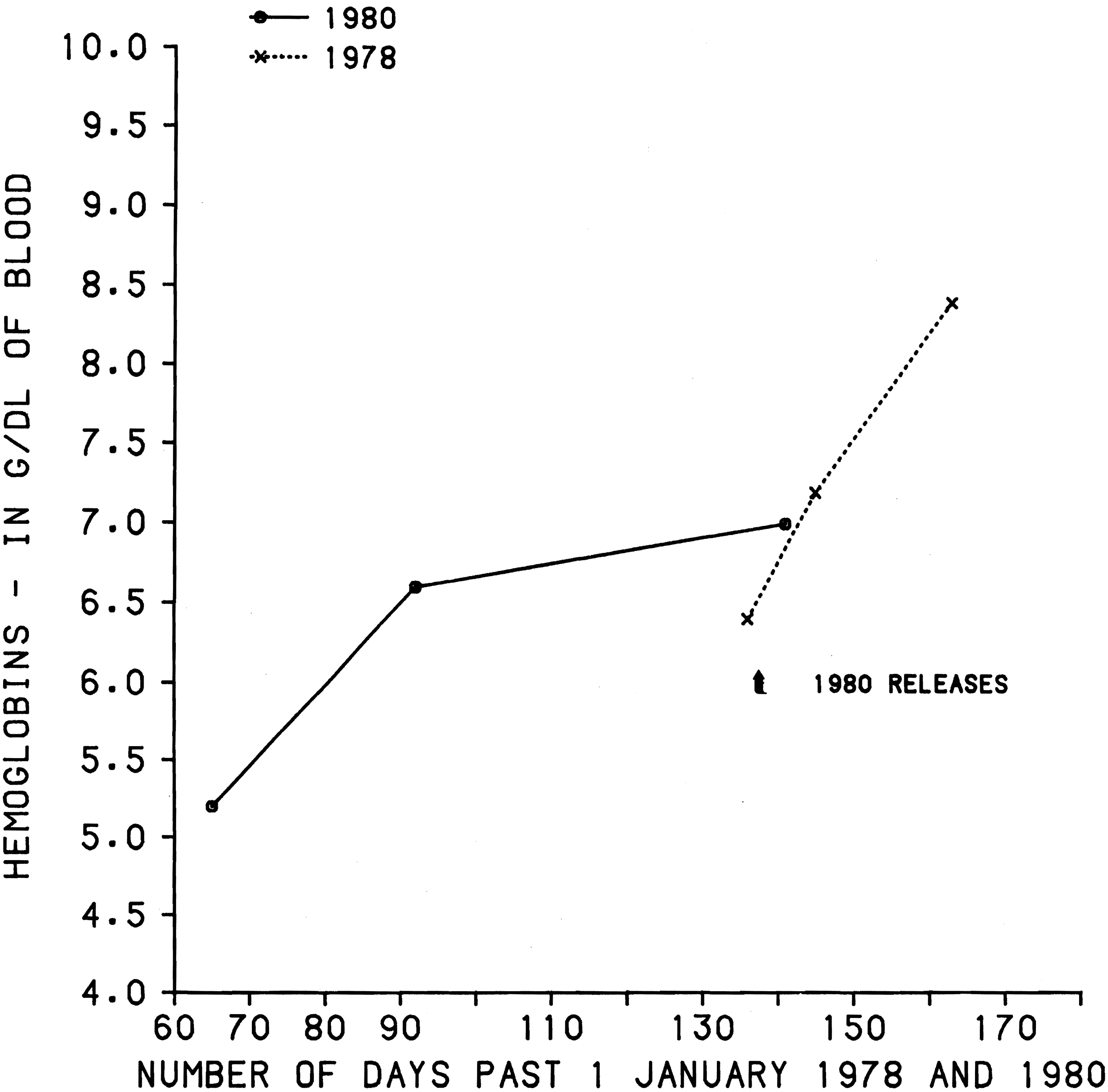


Figure 74.--Mean hemoglobin values of the Willard NFH coho salmon during the spring of 1978 and 1980.

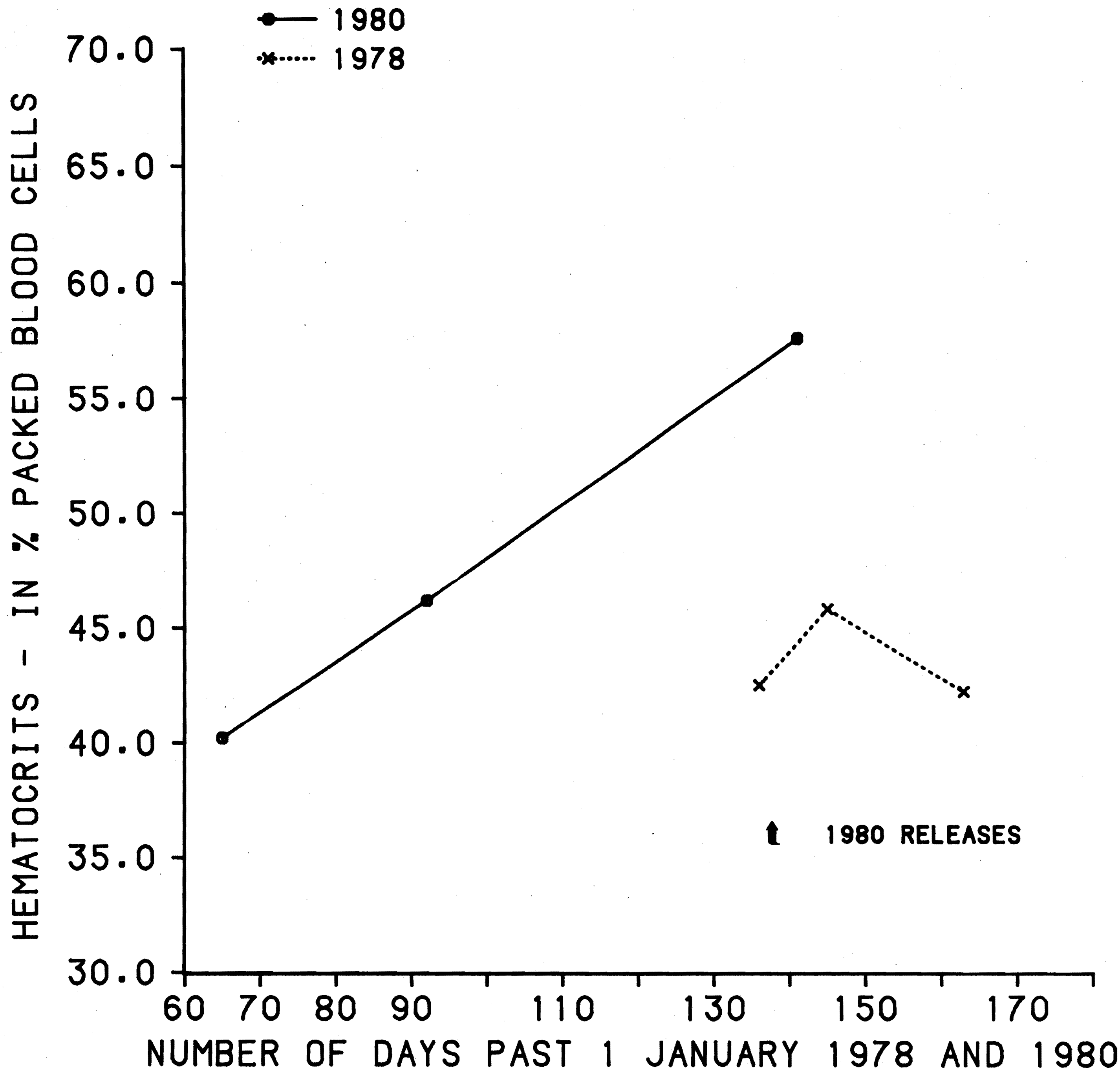


Figure 75.--Mean hematocrit values of the Willard NFH coho salmon during the spring of 1978 and 1980.

positive correlation between pooled hematocrit and gill Na^{+}-K^{+} ATPase values at the time of release in 1980 (Figure 76). Furthermore, there were no samples with hematocrits above the expected high value (52.5%) on 5 March 1980 and only 17% on 2 April.

The mean cell hemoglobin concentration (MCHC) had actually declined by the time of release, which is another indication that the fish were probably not stressed. However, even though high hematocrit values are generally not considered as indications of stress, the possibility of extreme hemoconcentration may be cause for concern. As the fish enter seawater, there is a further reduction in body water from osmosis.

IFAT-BKD

Specimens of Willard NFH coho salmon from the 3 March and 5 May sampling periods were examined for the presence of BKD organisms by the IFAT.

Only four specimens (6.7%) were found positive for BKD on 3 March, all in the posterior kidney, and all of very light intensity. Only one specimen (1.7%) was found positive for BKD on 5 May, and this was of moderate intensity (posterior kidney only). This is a low rate of infection in comparison to the 15-16% of samples positive for BKD at comparable release times in 1978. These data, plus the absence of any samples with extremely low hematocrits suggest an improved state of health over the 1978 releases.

Histopathology

A summary of pathological conditions observed is presented in Table 48. For comparative purposes, these data are further summarized with data from other hatcheries in Table 9.

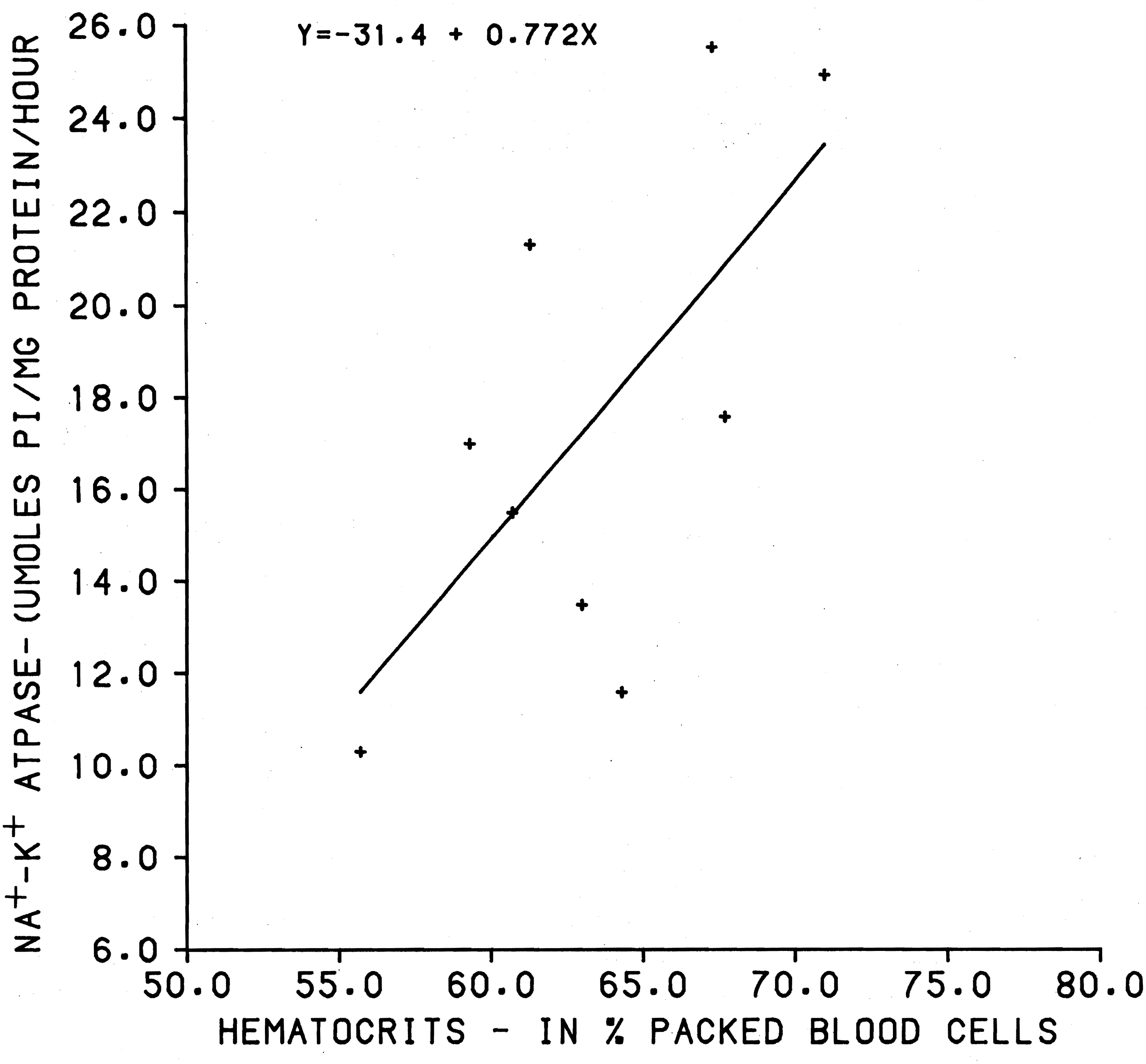


Figure 76.--Regression of pooled gill Na^+-K^+ ATPase activity on pooled hematocrit values of Willard NFH coho salmon at the time of release (24 May 1980). $r = 0.667$; $P < 0.05$ (for 7 d.f.).

Table 48.--Pathological conditions observed in 1980 Willard Hatchery coho salmon and their percentage of incidence.[a]

Organ and pathology	Incidence (%) Period 1 (severity)[b] I	II	III	total	Period 2 (severity) I	II	III	total	Period 3 (severity) I	II	III	total
Eye												
skeletal muscle lesions	63.3	0	0	63.3	46.7	0	0	46.7	78.3	0	0	78.3
Gills												
increased numbers of lymphocytes	80.0	16.7	0	96.7	66.7	16.7	0	83.3	41.7	58.3	0	100.0
epithelial cell formation	63.3	11.7	0	75.0	41.7	3.3	0	45.0	70.0	28.3	0	98.3
lymphatic telangiectasis of secondary	1.7	0	0	1.7	10.0	1.7	0	11.7	0	0	0	0
vascular telangiectasis of secondary lamellae	21.7	1.7	0	23.4	6.7	0	0	6.7	3.3	0	0	3.3
Olfactory sac												
focal mononuclear cell infiltration	78.3	20.0	0	98.3	95.0	5.0	0	100.0	93.3	5.0	0	98.3

a/ Brain tissue was processed and examined for all specimens, and there was no evidence of any pathology.

b/ I-recognizable (least severe); II-intermediate; III-severe.

In 1980, there were pronounced increases in pathological conditions of the eyes and gills between the first and last (at release) sampling periods. There was a doubling and tripling of intermediate (Class II) severity in several pathological conditions of the gills. By comparison, in 1978 (at a comparable release time), 40% of the fish had lesions of the skeletal muscle of the eye, 22% had increased numbers of lymphocytes in the gills, and 45% showed evidence of epithelial cell formation in the gills. There was never more than 3.5% of the fish with intermediate (Class II) severity of any lesion in 1978. Lesions of the olfactory sac were consistently high in 1980.

Summary

The serial sampling of Willard NFH coho salmon in 1980 indicated that gill Na^{+}-K^{+} ATPase profiles were spatially identical to those collected in 1978, and that releases were in accord with a timely peak. High Na^{+}-K^{+} ATPase values were seen in 50-60% of the samples at the time of release.

The general health of the fish was good, with very little evidence of latent BKD or clinical evidence of anemia or border-line anemia. A very high proportion (68%) of the samples had excessively high hematocrits at release, possibly due to hemoconcentration. This could have posed problems if the fish reached the high salinities in the ocean in this state.

Increases in the frequency and severity of certain lesions of the eyes and gills at the time of release are difficult to evaluate as a possible detriment to the overall health picture at this time.

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APPENDIX A

APPENDIX A

A quick reference chart to determine the calendar date (for year 1980) from the number of days past 1 January 1980 (days>Ja1).

Number of days past 1 January 1980	Calendar date
5	5 January
10	10 January
15	15 January
20	20 January
25	25 January
30	30 January
35	4 February
40	9 February
45	14 February
50	19 February
55	24 February
60	29 February
65	5 March
70	10 March
75	15 March
80	20 March
85	25 March
90	30 March
95	4 April
100	9 April
105	14 April
110	19 April
115	24 April
120	29 April
125	4 May
130	9 May
135	14 May
140	19 May
145	24 May
150	29 May
155	3 June
160	8 June
165	13 June
170	18 June
175	23 June
180	28 June

APPENDIX A.--cont.

Number of days past 1 January 1980	Calendar date
185	3 July
190	8 July
195	13 July
200	18 July
205	23 July
210	28 July
215	3 August
220	7 August
225	12 August
230	17 August
235	22 August
240	27 August