ASSESSMENT OF SMOLT CONDITION FOR TRAVEL TIME ANALYSIS

Annual Report 1988

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ABSTRACT

Estimates of migration rates and travel times of juvenile salmonids within index reaches of the Columbia River basin are collected through the Smolt Monitoring Program for use by the Fish Passage Center. With increased reliance upon travel time estimates in 1988 by the Fish Passage Center, this study was implemented to monitor the biological attributes of juvenile chinook salmon Oncorhynchus tshawytscha and steelhead trout O. mykiss used for the travel time estimates,

The physiological ability of fish to respond to stress was assessed by measuring levels of plasma cortisol, glucose, and chloride before and after a stress-challenge test. Most mid-Columbia and Snake river groups responded normally to the stress challenge exhibiting an increase in plasma glucose and cortisol and a slight decrease in chloride. Fish trucked to release sites were more stressed than those released directly from the hatchery, but most still responded to the stress challenge test normally. An abnormal or extreme stress response occurred when there were deviations from preferred protocol, disease problems at hatcheries, or when fish were trucked over long periods (7h).

The development of smoltification was evaluated by measuring gill Na^+K^+-ATPase, plasma thyroxine, purines, and body morphology. Most groups were similar at the hatcheries but differed as the migration to McNary Dam proceeded. Gill ATPase activity increased 2-3 fold during the first 20 days of migration, after which it changed little. Fish with longer in-river travel times appeared to be more smolted than those which were in the river for a shorter period of time.

The prevalence of bacterial kidney disease (BKD) in spring chinook salmon was evaluated using the enzyme linked immunosorbent assay (ELISA) and fluorescent antibody technique (FAT). Prevalence of BKD in groups tested using the ELISA method was as high as 99% at some downstream locations.

A review of indices is presented as a guide, to the development of an index of smolt condition and preliminary data are presented. An index could be used as a tool to synthesize information on fish condition to assist with management and evaluation of the Water Budget. .

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INTRODUCTION

As a part of the Northwest Power Planning Council's Fish and Wildlife Program, the Fish Passage Center (FPC) collects information on the migrational characteristics of juvenile salmon Oncorhynchus sp. and steelhead trout 0. mykiss in the Columbia River Basin This information is used primarily to help manage and evaluate the Water Budget, a volume of water used to enhance environmental conditions (flows) for seaward migrating smolts. Implicit in the Water Budget concept is that by augmenting flows, travel time of smolts can be decreased, thereby increasing survival via reductions in delayed migration and exposure to predators,

To evaluate the Water Budget, the FPC estimates survival and travel times for marked groups of smolts. Difficulties in obtaining unbiased estimates of survival in past years has led to reliance solely on travel times in 1988. Travel time is estimated as the number of days between date of release and median passage date at a downstream monitoring station, or as the number of days between median passage dates between two monitoring stations, e.g. Rock Island Dam to McNary Dam on the mid-Columbia River.

In addition to river flows, biological attributes, or smolt condition, such as levels of stress, extent of smoltification, and the prevalence and severity of diseases have been shown to affect the travel time and survival of smolts. Failure to measure such parameters in the past has resulted in the inability to interpret results of some survival and travel time estimates.

In 1988, this study was funded by the Bonneville Power Administration to measure levels of stress, smoltification, and bacterial kidney disease (BKD), and to conduct organosomatic examinations on selected marked groups used by the Fish Passage Center to estimate travel time. Part one of this report describes the biological attributes of smolts used to estimate travel time in 1988. Part two consists of an examination of indices and the feasibility of developing a smolt condition index as an aid for management and evaluation of the Water Budget.

PART ONE: BIOLOGICAL ATTRIBUTES OF SMOLTS USED TO ESTIMATE TRAVEL TIME

STUDY SITES AND FISH COLLECTION

Fish used in this study were from marked groups used by the Fish Passage Center (FPC) to estimate travel time in the Columbia and Snake rivers (Table 1). These fish included steelhead from Idaho Department of Fish and Game (IDFG), U.S. Fish and Wildlife Service (USFWS), Washington Department of Wildlife (WDW), and the Oregon Department of Fish and Wildlife (ODFW). Spring chinook salmon 0. tshawytscha originated from hatcheries operated by USFWS and IDFG. Fall chinook salmon were from hatcheries operated by Washington Department of Fisheries (WDF) and summer chinook salmon were from an IDFG hatchery.

The fish were marked using freeze branding techniques (Mighell 1969) as described in more detail by the Fish Passage Center (1988). Steelhead and subyearling fall chinook salmon were marked in the spring of 1988. Yearling chinook salmon were marked about 6 months before release.

To assess the level of smoltification fish were sampled one month, two weeks, and shortly before release from the hatcheries. At release, samples for stress and BKD (selected groups of chinook salmon) were also taken. Samples at release were collected before fish were subjected to disturbances related to hatchery release procedures (e.g. raceway drawdown, crowding, etc.) and prior to daily activities such as feeding. In addition, fish transported to remote release sites were sampled directly from the truck at the release site. Release site locations are shown in Figure 1. After release, smoltification and BKD (selected groups of chinook) of each group were assessed at the early, middle and late portions (about the 25, 50, and 75th percentiles) of their passage past Rock Island, Lower Granite, and McNary dams.

STRESS

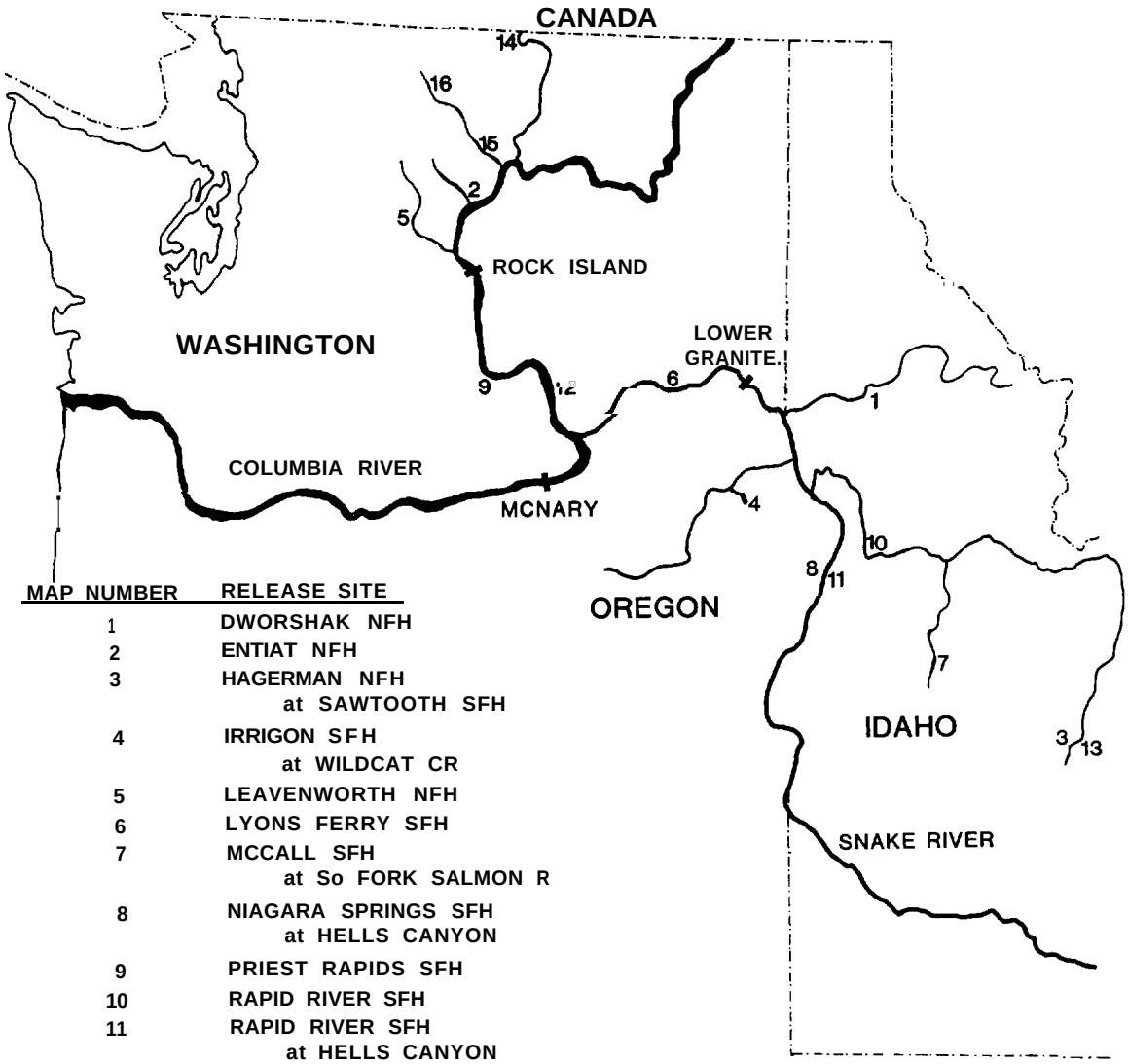
Methods and Materials

Levels of plasma cortisol, glucose, and chloride were measured to assess baseline stress levels of fish prior to release from each hatchery. In addition to a sample of 20 fish in a "resting" state as a baseline, a handling-stress challenge was used to assess ability of fish to respond to a standardized stress (Barton et al. 1985). In this challenge, 20 fish were netted, held out of water for 30 seconds, and returned to a container of water with a maximum loading of 30 $g \cdot L^{-1}$ (0.25 $lb \cdot gal^{-1}$).

Table 1. Fish sampled during spring, 1988, including hatchery, species, Fish Passage Center lot number (FPCLOT#), brand, and release site.

HATCHERY	SPECIES	FPCLOT#	BRAND	RELEASE SITE
mid-Columbia River				
Entiat NFH	SPCH	88153	RA-7H-1	Hatchery
Leavenworth NFH	SPCH	88154	RA-7T-1	Hatchery
Ringold SFH	SPCH	88271	LA-7F-3	Hatchery
Winthrop NFH	SPCH	88166	LA/RA-7C-l/3	Hatchery
Priest Rapids SFH	FACH[a]	88273	LA-R-l RA-R-2	Hatchery
Wells SFH	STHD	88351	LA-7U-1	Similkameen R.
	STHD	88353	RA-7U-3	Methow R.
Snake River				
Dworshak NFH	SPCH	88176	LA-T-2	Hatchery
Lyons Ferry SFH	FACH[b]	'88266	RA-7S-1	Hatchery
	FACH[a]	88267	RD-R-1	Hatchery
McCall SFH	SUCH	88000	RD-T-2	S. Fork Salmon R.
Rapid River SFH	SPCH	88002	RD-T-4	Hatchery
	SPCH	88003	LD-T-4	Hells Canyon
Sawtooth SFH	SPCH	88004	RD-T-l	Hatchery
Dworshak NFH	STHD	88185	RA-T-4	Hatchery
Hagerman NFH	STHD	88187	LD-T-2	Sawtooth SFH
Irriqon SFH	STHD	88090	RA-IF/IM-1	Wildcat Creek
Niagara Springs SFH	STHD	88016	LD-T-3	Hells Canyon

a Subyearling
b Yearling



MAP NUMBER	RELEASE SITE
1	DWORSHAK NFH
2	ENTIAT NFH
3	HAGERMAN NFH at SAWTOOTH SFH
4	IRRIGON SFH at WILDCAT CR
5	LEAVENWORTH NFH
6	LYONS FERRY SFH
7	MCCALL SFH at So FORK SALMON R
8	NIAGARA SPRINGS SFH at HELLS CANYON
9	PRIEST RAPIDS SFH
10	RAPID RIVER SFH
11	RAPID RIVER SFH at HELLS CANYON
12	RINGOLD SFH
13	SAWTOOTH SFH
14	WELLS SFH at SIMILKAMEEN R
15	WELLS SFH at METHOW R
16	WINTHROP NFH

figure 1 t . Map of the Columbia River basin showing release locations of marked groups of juvenile salmonids from hatcheries sampled in 1988.

After one hour, the fish were anesthetized and blood samples were taken. Additional baseline and handling-stress challenge samples were collected from groups released off-station by dip-netting fish from truck tanks at the release sites.

Plasma cortisol was analyzed using the radioimmunoassay approach of Redding et al. (1984). Plasma glucose was analyzed using an hexokinase enzymatic method (Sigma Diagnostics, St. Louis, Mo.); chloride concentrations were determined using a chloridometer. As a quality assurance, samples were analyzed in a random order with standards at regular intervals during the assays. Data were analyzed using analysis of variance (ANOVA) and Student-Newman-Keuls (SNK) multiple range tests, In the text, use of the term significant refers to a statistically significant difference at the probability $P < 0.05$.

Results

Stress results have been organized by area of release (mid-Columbia or Snake River) and species (yearling chinook or steelhead). A brief summary of measures of stress from each group are included in Table 2. All groups of yearling chinook salmon at mid-Columbia hatcheries sampled to assess their stress response were released directly from the raceways or rearing ponds. At release, responses to a handling-stress challenge test were normal, characterized by a significant increase in mean plasma cortisol (Figure 2). None of the mid-Columbia groups exhibited a significant change in mean plasma glucose in response to the stress challenge test (Figure 3). The mean level of glucose in resting fish from Ringold SFH was significantly lower than the levels of the other qroups at rest; after the challenge glucose levels remained low relative to the response of other groups. In response to the stress challenge, yearling chinook salmon from Rinqold SFH and Winthrop NFH had significant decreases in mean plasma chloride levels (Figure 4). The overall stress response of fish at Ringold SFH differed from that of other groups as they had the largest increase in plasma cortisol, lowest levels of plasma glucose, and a large decline in plasma chlorides.

Among the six groups of yearling chinook salmon sampled at the Snake River hatcheries, only those from McCall SFH and Rapid River SFH (LD-T-4 brand) were trucked to their release sites. All others were released directly from the hatchery. Chinook salmon released at the Snake River locations had relatively small changes in blood parameters in response to stress challenqe tests compared to mid-Columbia groups. Water temperatures during stress challenges of Snake River yroups ranged from 0°C to 5°C, and from 5 to 13.9°C for tests conducted with groups released in the mid-Columbia River.

Yearling chinook salmon sampled in the Snake River Basin had a typical increase in cortisol in response to the stress challenge tests at the hatchery and again after trucking (Figure 5). At the hatchery, fish from Sawtooth SFH had unusually high variability in resting levels of

Table 2. Summary of stress and smoltification results from juvenile salmonids collected at the hatcheries and at Rock Island Dam (mid-Columbia groups), Lower Granite Dam (Snake groups), and McNary Dam, spring 1988.

Hatchery Brand	STRESS	SMOLTIFICATION
Chinook Salmon ---------- mid-Columbia River ----------		
Entiat NFH RA-7H-1	-normal	-decline in ATPase prior to release
Leavenworth NFH RA-7T-1	-normal	-decline in ATPase prior to release -high ATPase at end of migration
Ringold SFH LA-7F-3	-low glucose and chloride levels -significant decrease in chloride after stress test	normal
Winthrop NFH LA/RA-7C-1/3	-low chloride levels after stress test	-decline in ATPase prior to release -high ATPase as passed Rock Island Dam
Priest Rapids SFH(age 0)	- no sample	decline in ATPase prior to release
Chinook Salmon ---------- Snake River ----------		
Dworshak NFH LA-T-2	-normal	-normal, very silvered during migration
Lyons Ferry SFH(Age 1) RA-7S-1	-low chloride levels	-ATPase very high at hatchery -T4 high at McNary Dam
Lyons Ferry SFH(Age 0) RD-R-1	- no sample	-normal
McCall SFH RD-T-2	-normal	-high ATPase at McNary Dam
Rapid River SFH RD-T-4	-low cortisol level after stress test	-normal

Table 2. (continued) Summary of stress and smoltification results from juvenile salmonids collected at the hatcheries and at Rock Island Dam (mid-Columbia groups only), Lower Granite Dam (Snake groups only), and McNary Dam, spring 1988.

	STRESS	SMOLTIFICATION
Chinook Salmon	Snake River	
Rapid River SFH LD-T-4	-high variability in glucose levels -significant decline in chloride in response to stress test at truck	-normal
Sawtooth SFH RD-T-1	-normal	-normal
Steelhead	mid-Columbia River	
Wells SFH LA-7U-1	-high glucose levels -high variability in glucose and chloride	-ATPase declined prior to release
RA-7U-3	- same as above	- same as above
Steelhead	Snake River hatcheries	
Dworshak NFH RA-T-4	-normal	-normal
Hagerman NFH LD-T-2	-normal	-ATPase low at the hatchery
Irrigon SFH RA-IF/IM-1	-normal	-normal
Lyons Ferry SFH LA/RA-S-l/3	-low chloride levels -significant decrease in chloride levels in response to stress test	-normal
Niagara Springs SFH LD-T-3	-low glucose -chloride much lower after trucking than before trucking -significant decrease in chloride after stress test at release site	-ATPase low at hatchery

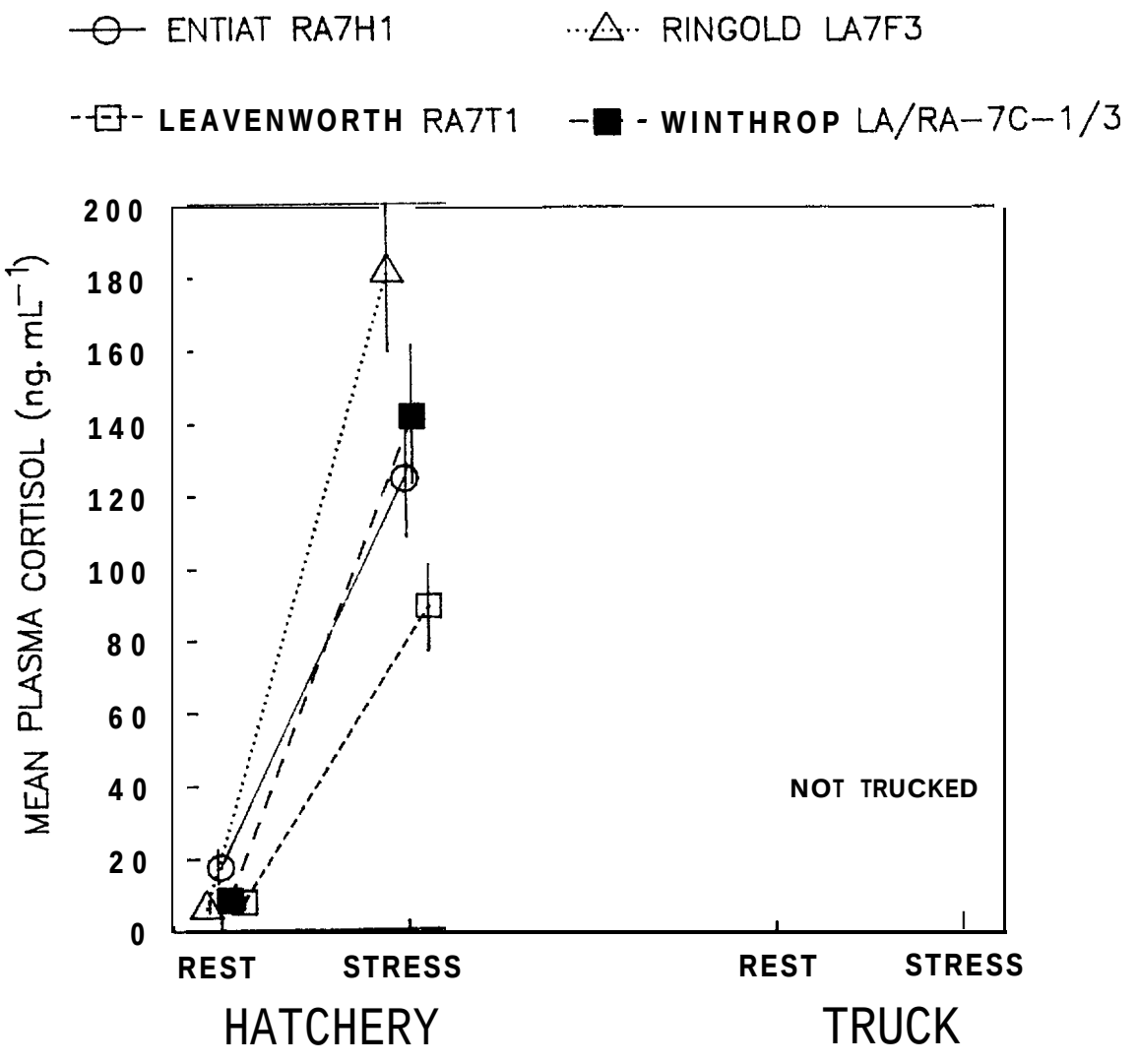


Figure 2. Changes in mean plasma cortisol of yearling chinook salmon from mid-Columbia hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY). Vertical lines represent 95% confidence intervals.

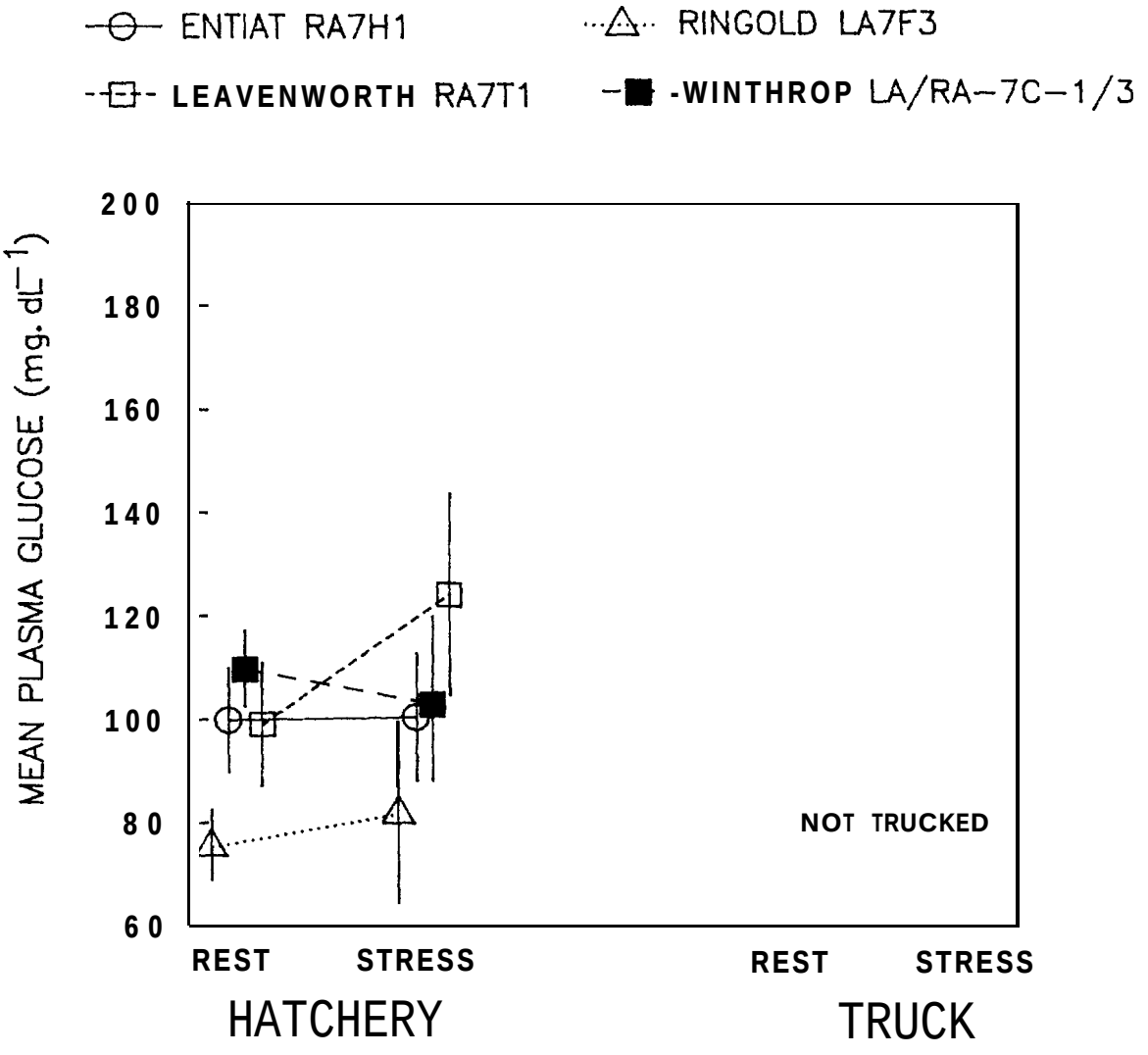


Figure 3. Changes in mean plasma glucose of yearling chinook salmon from mid-Columbia hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY). Vertical lines represent 95% confidence intervals.

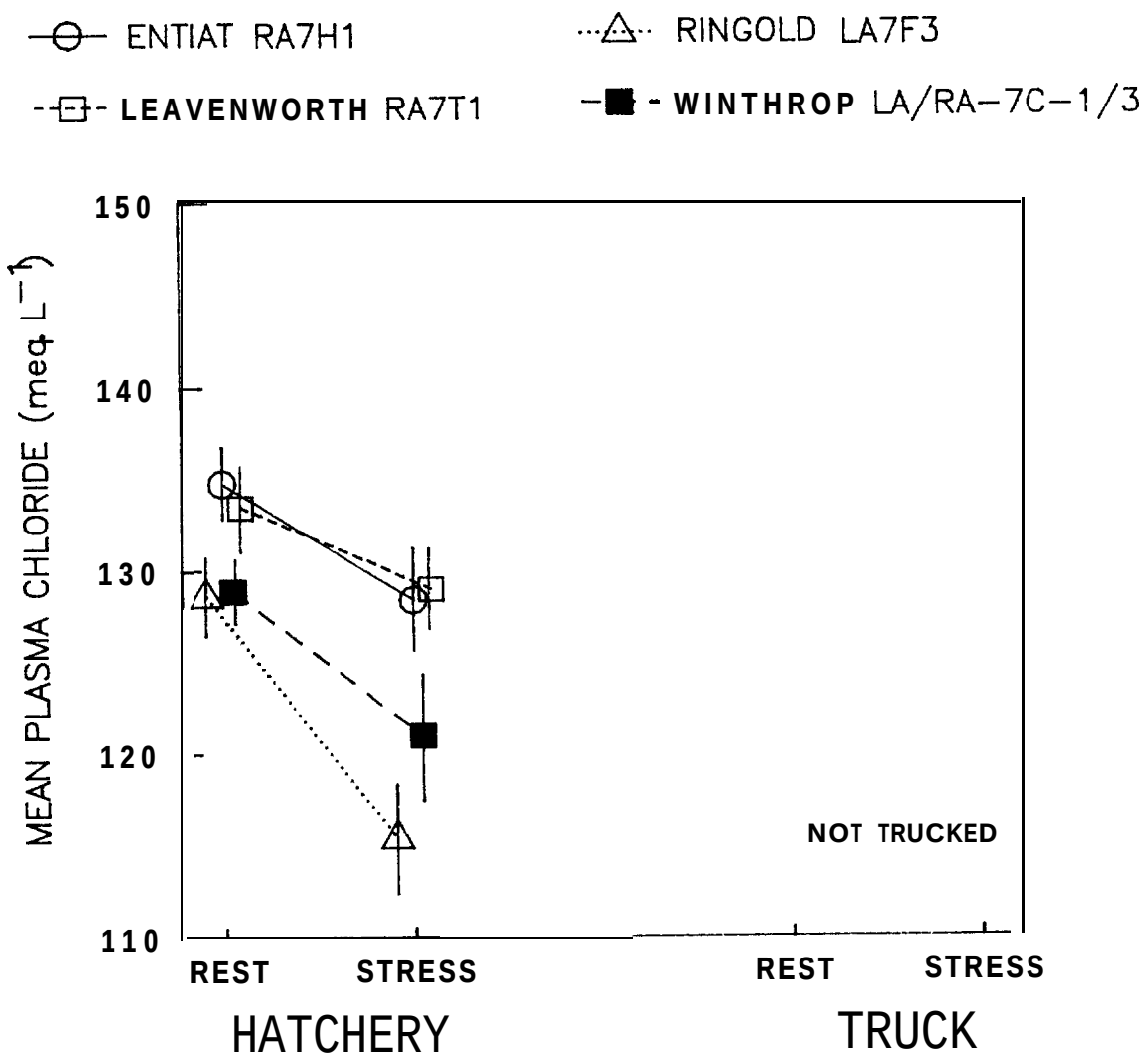


Figure 4. Changes in mean plasma chloride of yearling chinook salmon from mid-Columbia hatcheries , spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenqe test (STRESS) at the hatchery (HATCHERY). Vertical lines represent 95% confidence intervals.

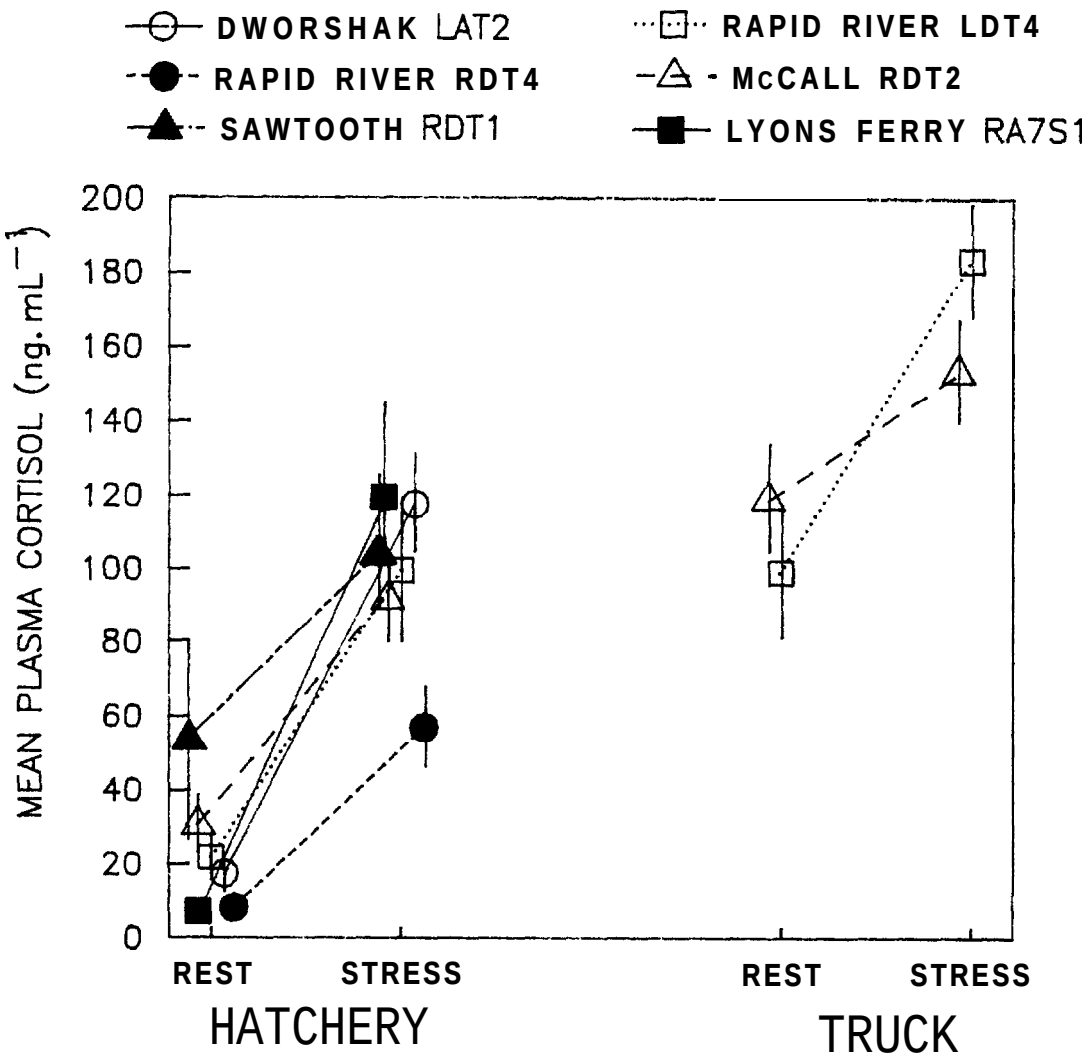


Figure 5. Changes in mean plasma cortisol of yearling chinook salmon from Snake River hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals,

cortisol and fish from Rapid River (RP-T-4) responded with a relatively small increase in cortisol compared to other groups at the hatchery. After transportation to the release sites, cortisol response to the stress challenge test appeared normal. The variability of the mean glucose response in the Rapid River (LD-T-4) group trucked to Hells Canyon was unusual inasmuch as variability was high and the glucose response at the truck was significantly different from the response at the hatchery (Figure 6).

The stress challenge tests conducted at the hatchery produced significant reductions in mean plasma chloride in most Snake River groups (Figure 7). After being trucked to the release site at the South Fork of the Salmon River, fish from McCall SFH were still able to maintain levels of plasma chloride near those observed at the hatchery and it did not decrease significantly in response to the challenge test; a desirable attribute. Fish trucked to Hells Canyon from Rapid River (LD-T-4) were not able to maintain chloride levels after the test. They had the largest increase in cortisol, high variability in glucose levels, and a significant decline in plasma chloride in response to the additional stress from the challenge test at the truck.

Steelhead from Wells SFH were trucked to release sites on the Methow River (RA-7U-3) and the Similkameen River (LA-7U-1); only those released at the Methow River were sampled at the release site. Stress challenge tests at the hatchery and release sites elicited a normal increase in the mean plasma cortisol of both groups (Figure 8). Mean plasma glucose concentrations did not change significantly in response to the stress challenge tests (Figure 9). Variability in glucose levels of both groups were unusually high, both at the hatchery and after transportation (RA-7U-3 only). Neither group exhibited a significant change in mean plasma chloride in response to the stress challenge, but variation was unusually high in all samples (Figure 10).

Steelhead released in the Snake River drainage were trucked to remote release sites from Hagerman NFH, Irrigon SFH, and Niagara Springs SFH whereas fish from Dworshak NFH and Lyons Ferry SFH were released at the hatchery. Stress responses of these five steelhead groups were characterized by a significant increase in mean plasma cortisol concentration (Figure 11). The response was similar both before and after transportation indicating adequate scope for a cortisol response to the challenge after fish experienced transportation. However, staelhead from Niagara Springs SFH (LD-T-3) appeared stressed after 7h of transportation and had higher resting levels of cortisol in the truck compared to fish from Hagerman NFH (LD-T-2) that were transported 3h. Steelhead at Niagara Springs SFH had relatively low levels of glucose at rest and after the stress challenge at the hatchery (Figure 12). After transportation to the release site, steelhead did not respond with a significant change in glucose in any group. At the hatchery, the group from Lyons Ferry SFH exhibited a significant decline in mean plasma chloride (Figure 13). The group from Niagara Springs SFH was the only one unable to maintain plasma ion levels, after transportation resulting in a significant decline in mean plasma chloride.

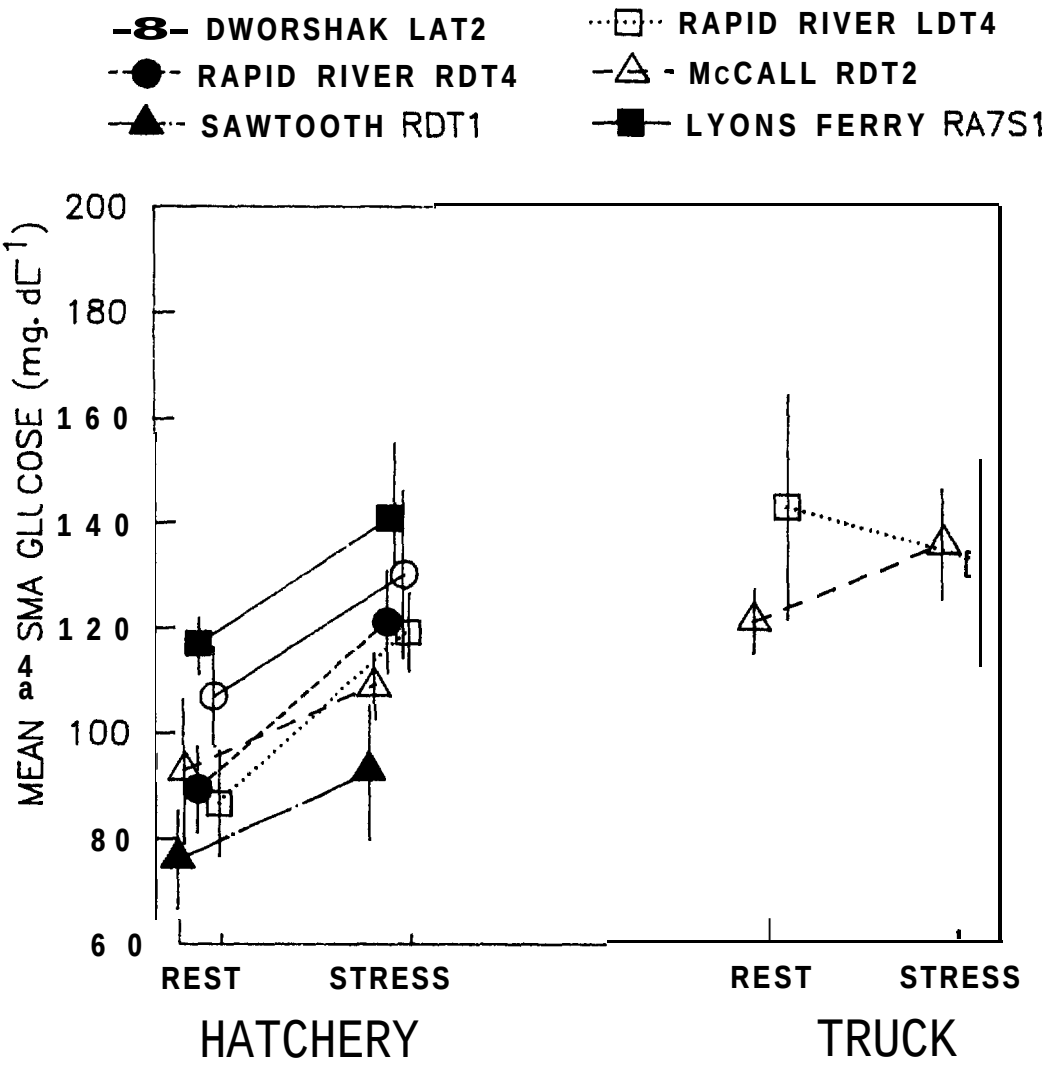


Figure 6. Changes in mean plasma glucose of yearling chinook salmon from Snake River hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical. lines represent 95% confidence intervals.

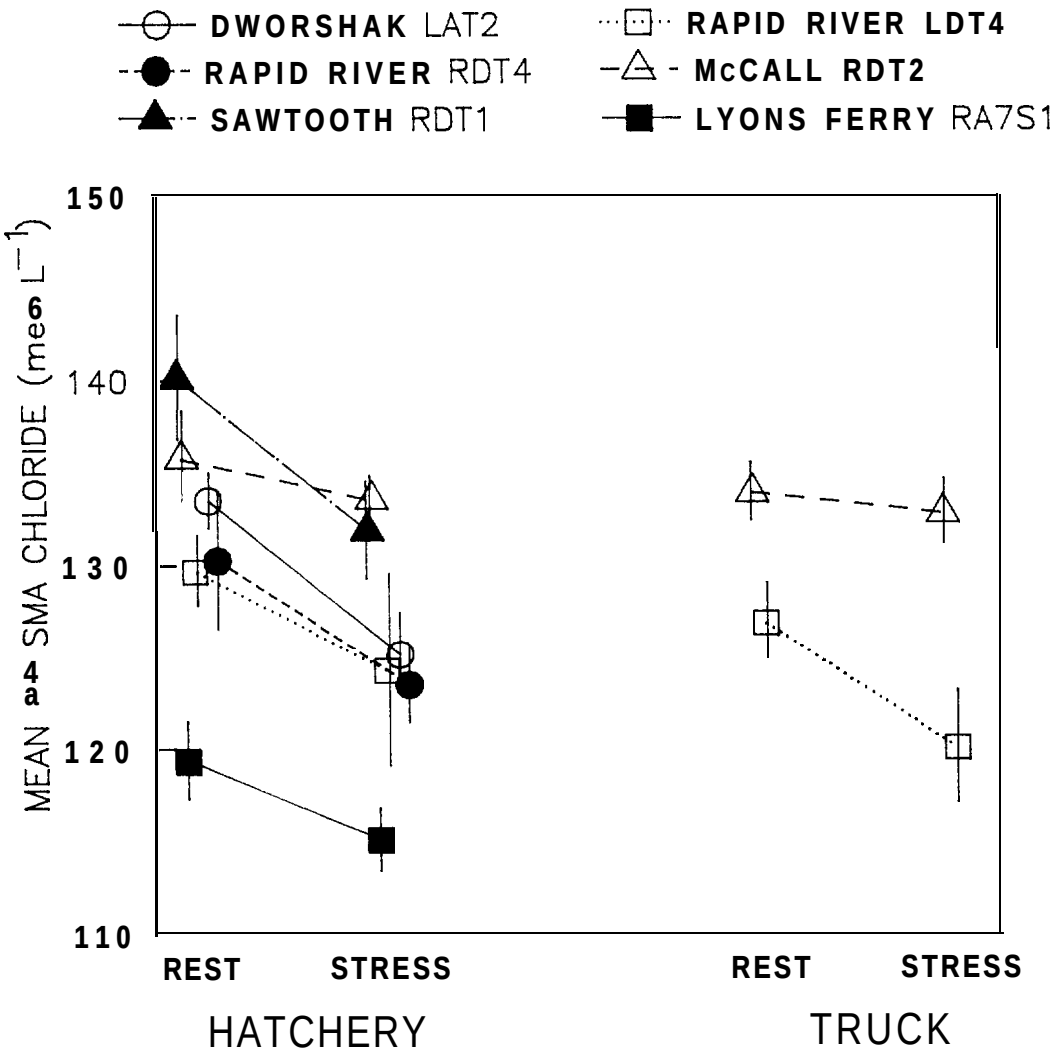


Figure 7. Changes in mean plasma chloride of yearling chinook salmon from Snake River hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

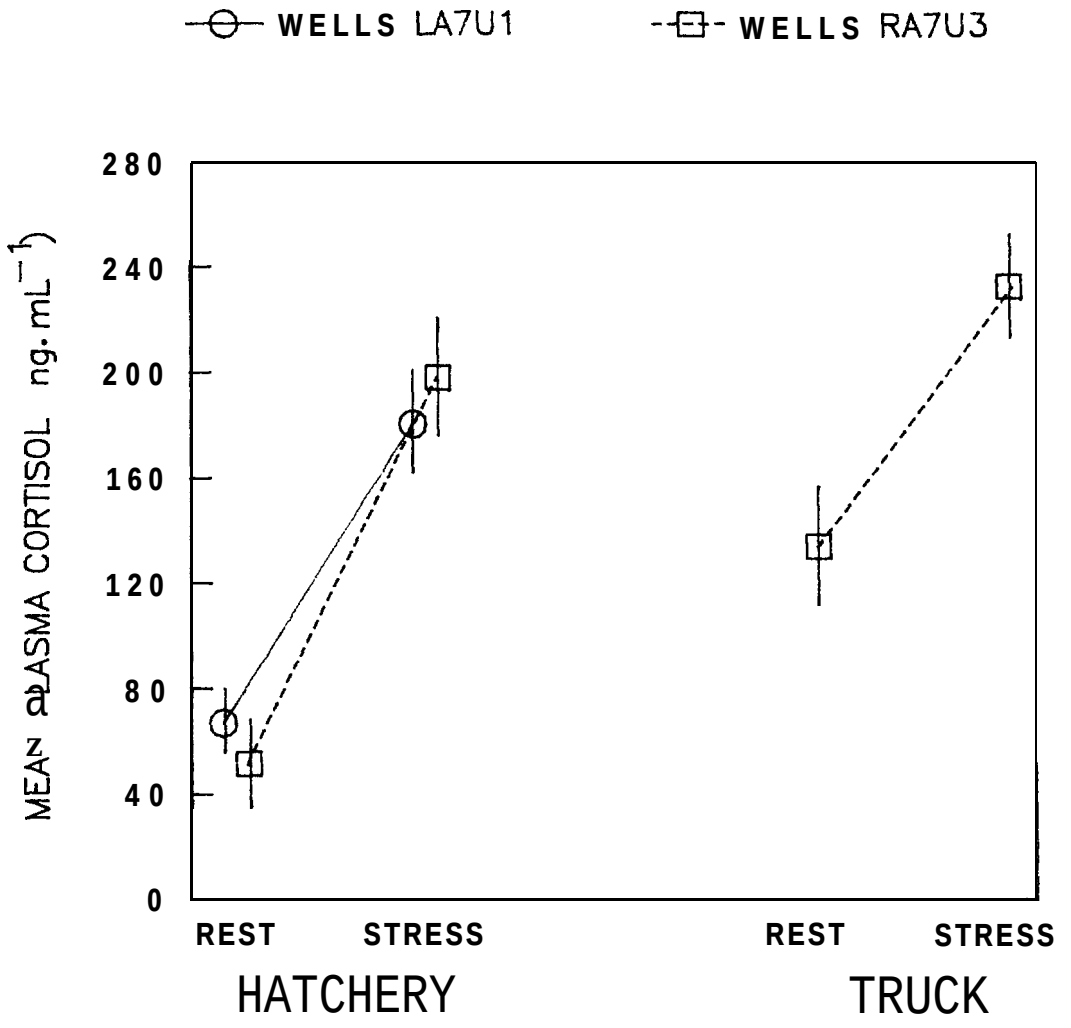


Figure 8. Changes in mean plasma cortisol of steelhead trout from mid-Columbia hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

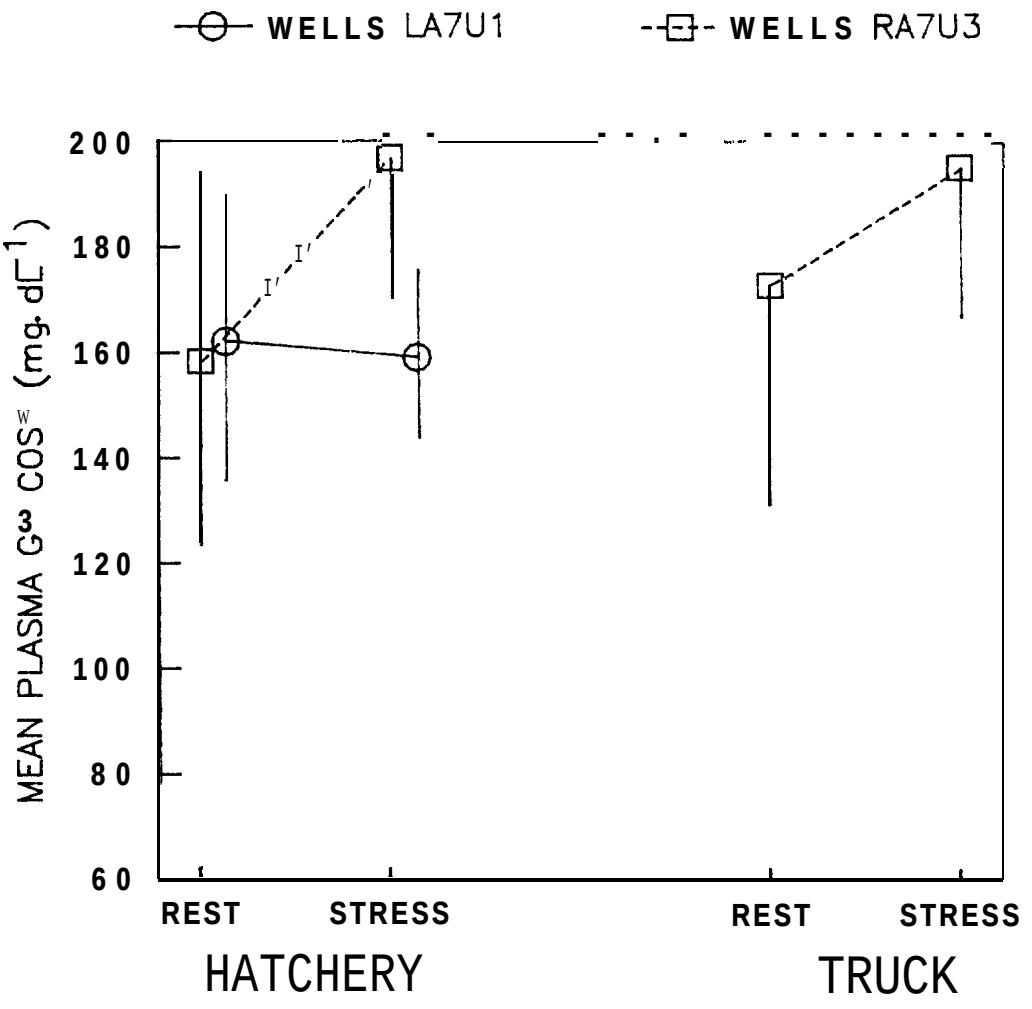


Figure 9. Changes in mean plasma glucose of steelhead trout from mid-Columbia hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

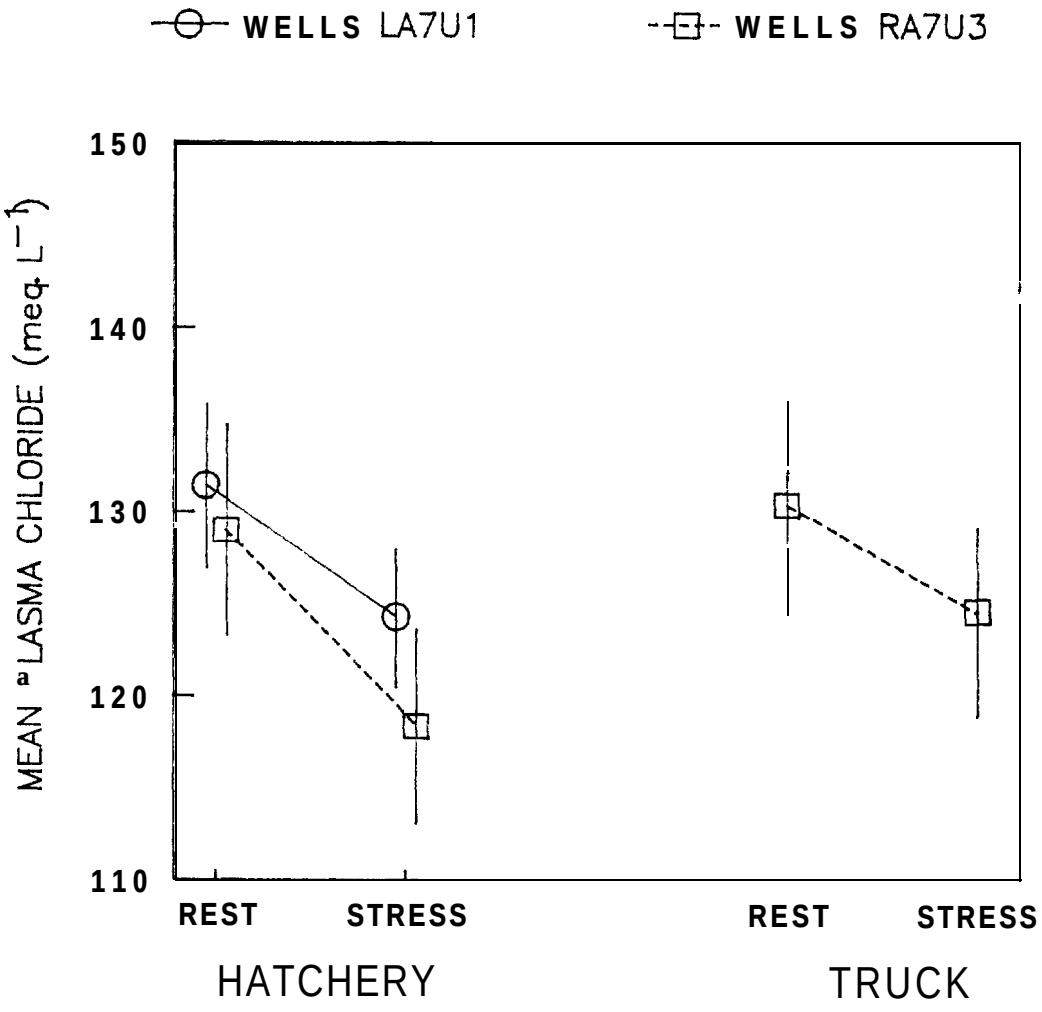


Figure 10. Changes in mean plasma chloride of steelhead trout from mid-Columbia hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

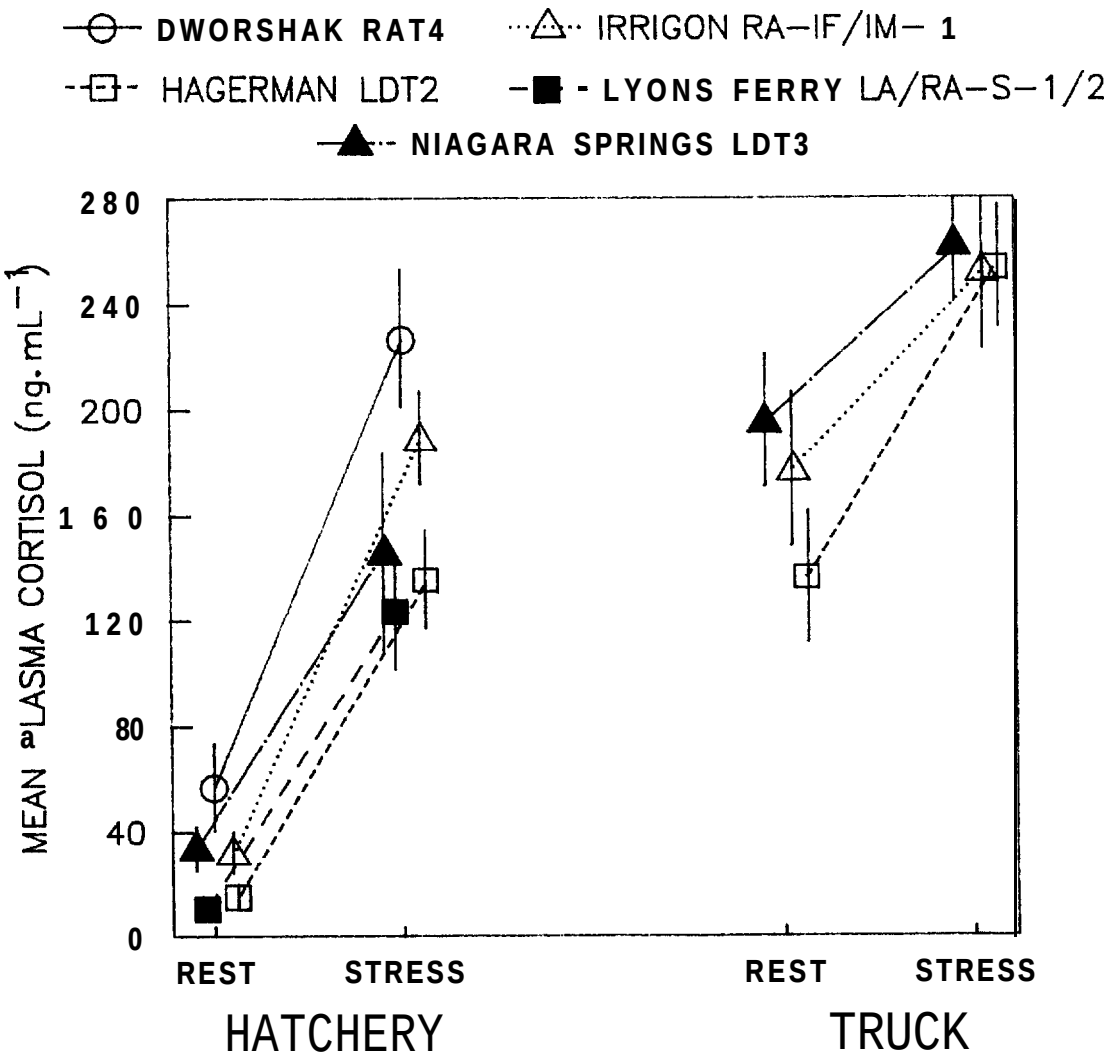


Figure 11. Changes in mean plasma cortisol of steelhead trout from Snake River hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

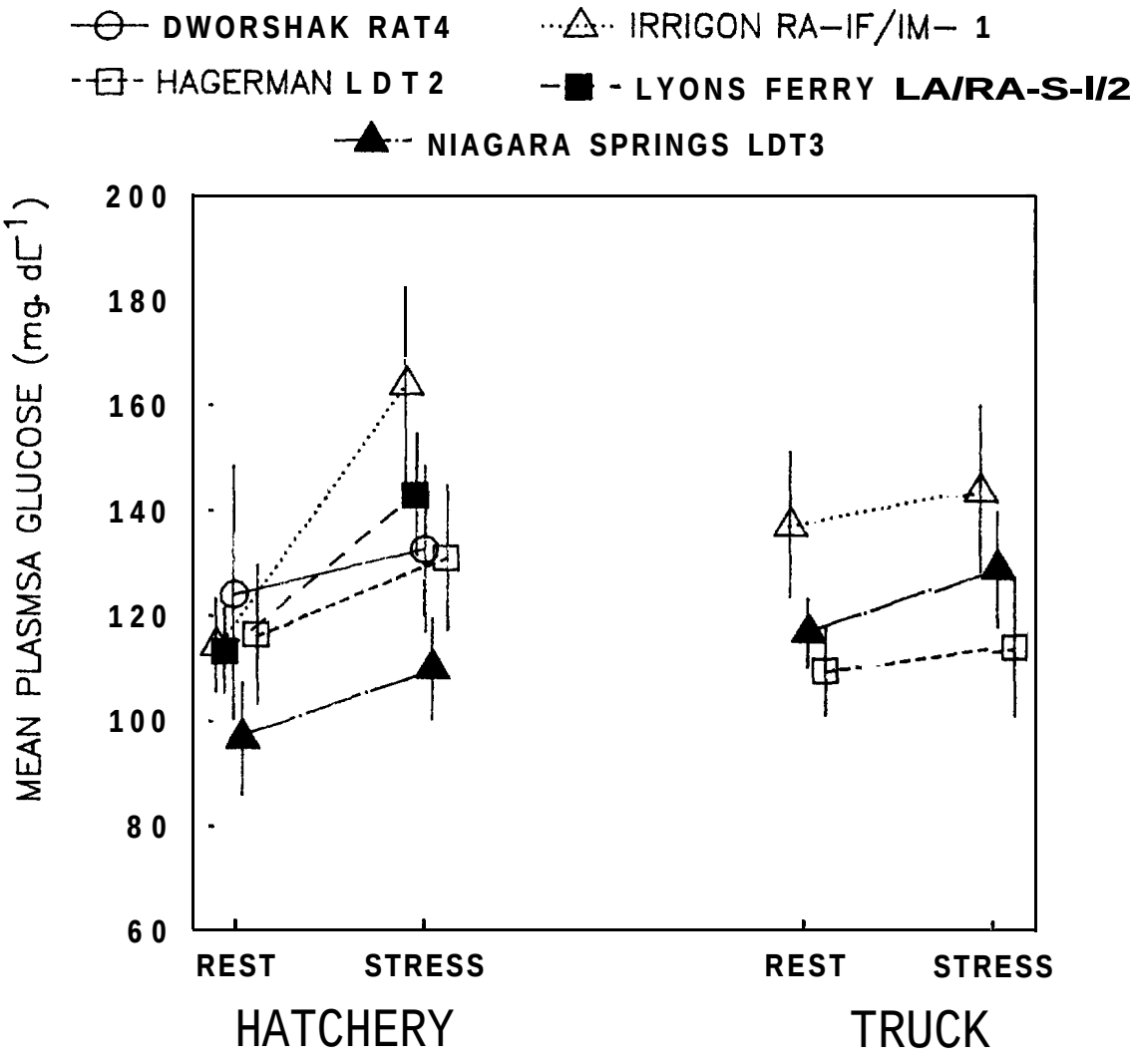


Figure 12. Changes in mean plasma glucose of steelhend trout from Snake River hatcheries, spring **1988.** Samples were collected from FISH in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again AFTER transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

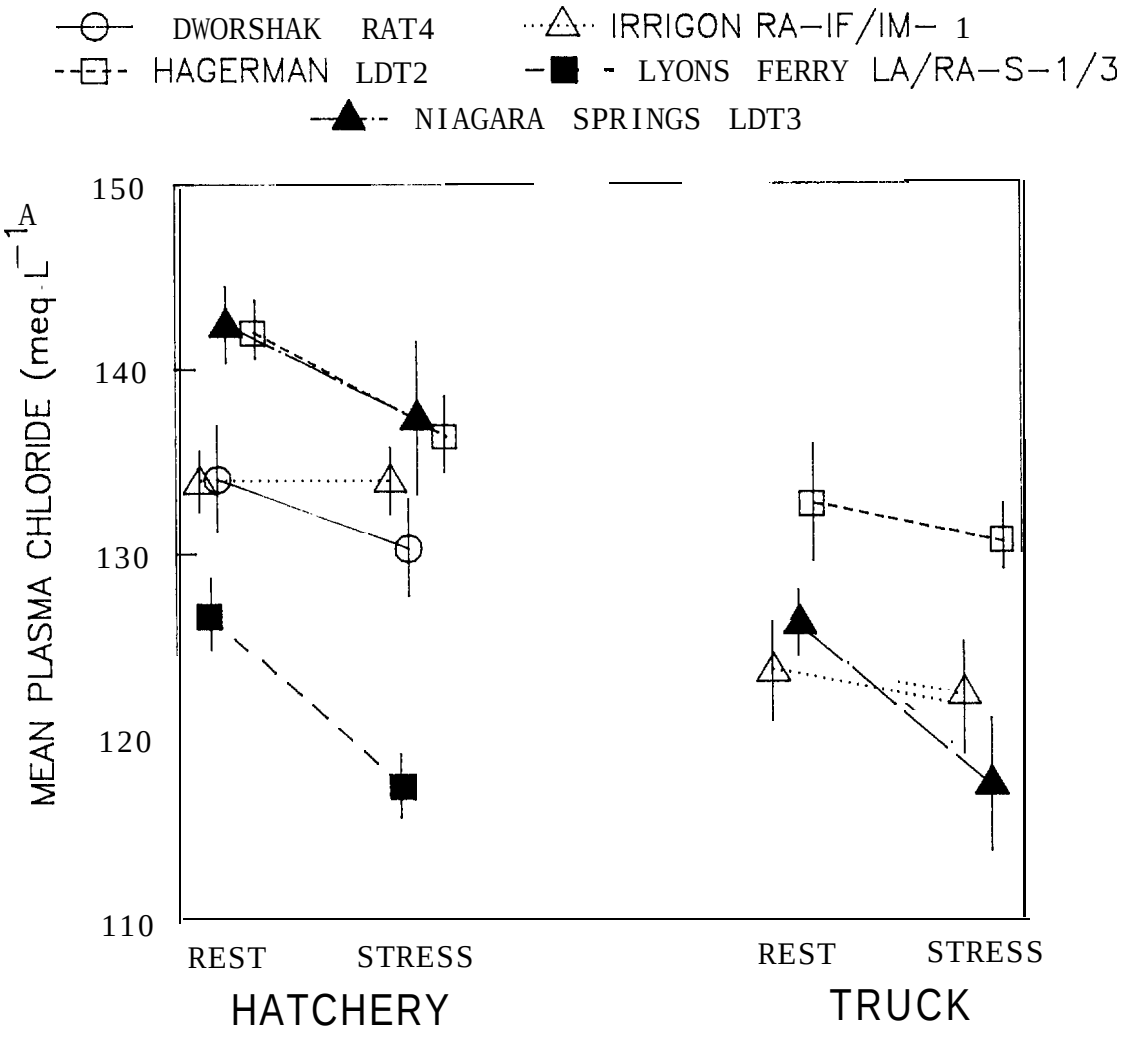


Figure 13. Changes in mean plasma chloride of steelhead trout from Snake River hatcheries, spring 1988. Samples were collected from fish in a resting state (REST) and one hour after a stress challenge test (STRESS) at the hatchery (HATCHERY) and again after transportation to the release site (TRUCK). Vertical lines represent 95% confidence intervals.

Discussion

Stress is the physiological response by which an animal tries to maintain or re-establish normal metabolism (Pickering 1981). Stressors such as transportation or the handling-stress challenge test used in this study normally elicit a stress response characterized by hypercortisolemia, hyperglycemia, and hypochloremia. Specific criteria for normal stress responses of smolts are lacking, although normal blood chemistry values have been estimated for rainbow trout and juvenile coho salmon (Barnhart 1969; Wedemeyer and Chatterton 1971). Inasmuch as normal range estimates are not available, interpretation in this study is based on comparisons of the response of an individual group to other similar groups.

The measures of the stress response used in this study may not he completely independent of smoltification. For example, levels of resting and post-stress plasma cortisol are known to increase in coho salmon during smoltification. Altered carbohydrate metabolism is another change associated with smoltification (Wedemeyer et al. 1980). Specifically, glucose metabolism is known to be sensitive to differences in feeding ration and Parr-smolt transformation (Wedemeyer 1976; Woo et al. 1978). For these reasons the interpretation of measures of stress response should be approached conservatively.

Responses to the handling-stress challenge test were not correlated with water temperature at the time of the test. However, among the spring chinook salmon, cortisol response to the challenge tended to be smaller in fish at Snake River hatcheries than at Columbia River hatcheries, Water temperatures ranged from 0°C to 5°C for challenge tests at the Snake River sites and 5°C to 13.9°C for those at mid-Columbia River sites. Strange et al. (1977) found that juvenile cutthroat trout acclimated to 23°C had the same initial cortisol concentration as trout acclimated to 9°C and a similar post-stress response during the first hour after the stressor. In this study, levels of cortisol among resting fish at the Columbia River hatcheries were all less than 20 $ng \cdot mL^{-1}$ but were as high as 53 $ng \cdot mL^{-1}$ at Sawtooth SFH. When Strange (1980) examined yearling channel catfish they found higher concentrations of cortisol at 10°C, a relatively low temperature for channel catfish, compared to 20°C and 30°C at which basal levels of cortisol were similar. Water temperature effects on the resting levels or stress response in juvenile salmonids is possible, but the lack of correlation between temperature and stress response suggests no effect in this study.

Although we recognize that smoltification or water temperature may be a consideration when interpreting the response to the handling-stress challenge test, some conclusions can be drawn from the results. Among groups of chinook salmon, fish at Ringold SFH had relatively low glucose levels and a substantial decline in plasma chloride after the challenge at the hatchery, possibly due to reduction in ration or the stress of low oxygen levels known to be present prior to release. At Sawtooth SFH resting fish had exceptionally high levels of cortisol, but this can be attributed to cleaning the raceway about one hour before sampling, a

departure from preferred protocol for this study. The fish released at Rapid River had a relatively small cortisol response at the hatchery while fish trucked to Hells Canyon had highly variable glucose values and responded to the challenge test with a large decline in plasma chloride. These deviations may be associated with disease problems at Rapid River SFH. Among steelhead groups, fish from Wells SFH had highly variable glucose values suggesting that some individuals were more stressed than others, possibly due to the marking process, which was completed as little as 20 h before release. Steelhead from Niagara Springs SFH had relatively low glucose levels at the hatchery and after being trucked responded to the additional stress of the challenge test with an unusual decline in plasma chloride. Specific groups discussed above responded differently to the handling stress challenge test compared to most groups, enabling us to use the general response as the norm.

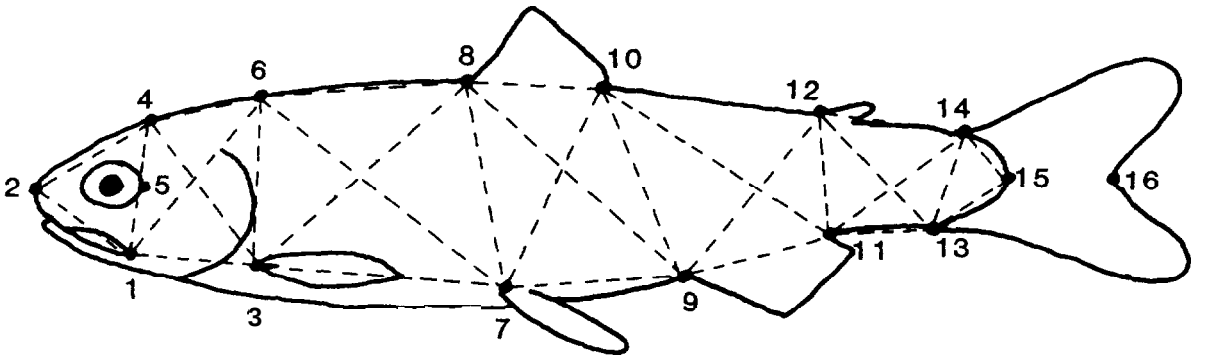
SMOLTIFICATION

Methods and Materials

Gill Na+-K+ adenosine triphosphatase (Na^+-K^+ ATPase) activity, plasma thyroxine levels (T_4), purines, and body morphology were used to evaluate the extent of smoltification. Gill filament samples were taken and assayed for Na+-K+ ATPase activity using the method of Zaugg (1982). Samples were analyzed in random order with known phosphate standards at regular intervals during the assay. Plasma samples were assayed for thyroxine using the radioimmunoassay described by Dickhoff et al. (1978) and modified by Specker and Schreck (1982). The data on ATPase and thyroxine were analyzed using ANOVA and SNK; statistical differences reported refer to $P < 0.05$.

The degree of silvering was quantitatively measured by determining the amount of guanine and hypoxanthine in skin and scales using the enzyme assay described by Staley (1984). Silvering is due to the deposition of purines, mainly guanine (Gn) and hypoxanthine (Hx), in the skin and scales of young salmonids during the smolt transformation (Sumner 1944; Markert and Vanstone 1966; Nicol and van Baalen 1968; Lee et al. 1969). By measuring the amount of purines present in skin and scales, a quantitative measurement of silvering is obtained. The purine content is being investigated as a quantitative measure to determine the validity of using visual observations of silvering in a smoltification index.

Morphological attributes of selected groups of fish collected at the hatchery and at McNary dam were compared. Photographs of each fish were used for measurement of selected characteristics (Figure 14) using methods adapted from Winans (1984). A digitizer was used to record X,Y coordinates of specific points on photographs of each fish, forming a truss network (Bookstein et al. 1985). The actual length of each line segment was calculated using a scaling factor. For each group of fish, a standard



1 Posteriormost point of maxillary
2 Anterior tip of snout at upper jaw
3 Origin of pectoral fin
4 Point on neocranium from right angle of snout and posteriormost aspect of eye
5 Posteriormost point of eyeball
6 Point on neocranium from right angle of origin of pectoral fin and tip of snout
7 Origin of pelvic fin
a Origin of dorsal fin
9 Origin of anal fin
10 Insertion of dorsal fin
11 Insertion of anal fin
12 Origin of adipose fin
13 Dorso-anterior attachment of caudal fin
14 Ventro-anterior attachment of caudal fin
15 Base of middle caudal rays
16 Fork of caudal fin

Figure 14. Schematic of smolt showing points identifying Line segments digitized for morphological c analysis, 1988.

body size (fork length) and average lengths for each line were calculated. Predicted line lengths were estimated for the standard body size using log-linear regression functions (Bookstein 1985). Changes in these line lengths approximate changes in body shape. The data were analyzed using SAS (SAS 1985).

Results

Smoltification results have been organized by area of release (mid-Columbia or Snake River), species (chinook salmon or steelhead), and age (yearling or subyearling). A brief summary of measures of smoltification of each group are included in Table 3. At the hatcheries, mean gill Na^+-K^+ ATPase activities of most yearling chinook salmon from the mid-Columbia and Snake rivers were similar (Figure 15 and 16). Gill ATPase activities of spring chinook salmon from Entiat, Leavenworth, and Winthrop NFH declined prior to release. Mean ATPase of all yearling chinook salmon groups increased progressively as they passed Rock Island Dam (mid-Columbia groups) and Lower Granite Dam (Snake groups). Excluding Winthrop, mean ATPase activities of groups from the mid-Columbia continued to increase as they passed McNary Dam. Fish from Winthrop NFH exhibited high ATPase levels as they passed Rock Island Dam and relatively constant levels throughout the remainder of the migration. The "early" Winthrop NFH sample at McNary Dam was quite low, but this sample represents fish after only 6% of the migration had past, unlike the other groups', whose early sample was nearer the 25th percentile of passage. Mean ATPase activity of the group from Leavenworth NFH was significantly higher than the others in the late part of the migration.

Yearling fall chinook salmon from Lyons Ferry SFH had much higher ATPase activities in the hatchery than yearling spring and summer chinook salmon from all other hatcheries (Figure 16). However, the Lyons Ferry group did not show the progressive increase in ATPase after release that other groups did. Gill ATPase of most yearling chinook salmon from the Snake River hatcheries was leveling off by the date they passed McNary, though ATPase activities of fish from McCall and Sawtooth SFH were still increasing. Yearling summer chinook salmon from McCall SFH exhibited the highest mean ATPase activity of any group sampled.

Compared to yearling fall chinook salmon at Lyons Ferry SFH, sub-yearlings at Lyons Ferry SFH and Priest Rapids SFH had relatively low ATPase activities at the hatchery (Figure 17). Mean ATPase levels of yearlings at Lyons Ferry SFH and sub-yearlings at Priest Rapids SFH declined prior to release, while sub-yearlings at Lyons Ferry SFH were increasing dramatically. At McNary Dam, mean ATPase levels of the sub-yearlings were higher than the yearlings.

Groups of steelhead from the mid-Columbia and Snake river hatcheries had similar mean gill ATPase activities at the hatchery, although the two groups at Wells SFH declined before release (Figure 18). The groups at

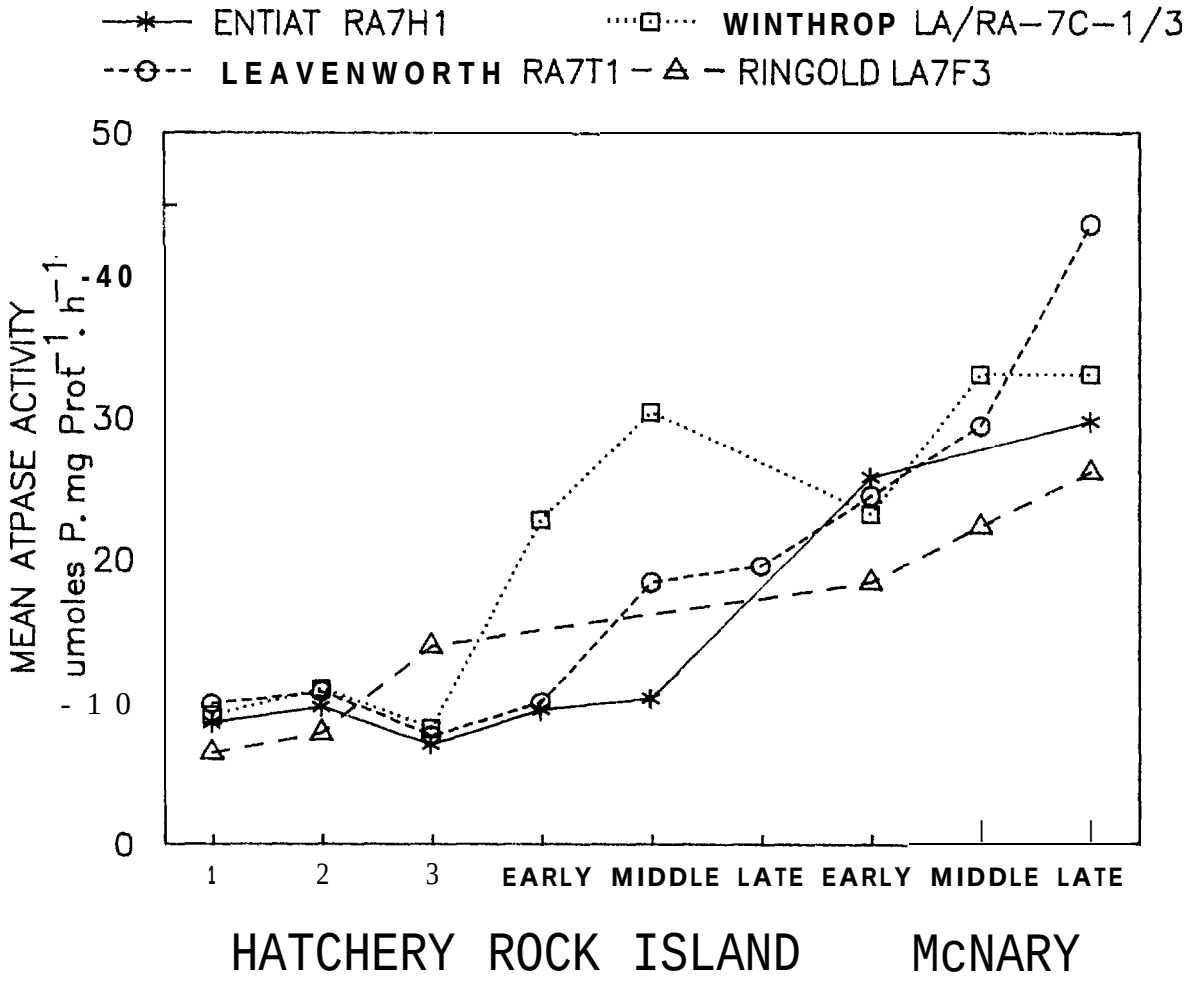


Figure 15. Mean Gill Na^+-K+ ATPase activity of spring chinook salmon from mid-Columbia hatcheries, spring 1988. Samples were collected one month, two weeks, and shortly before release (1,2,3 respectively) and again at the early, middle, and late portions of the migrations past Rock Island and McNary dams.

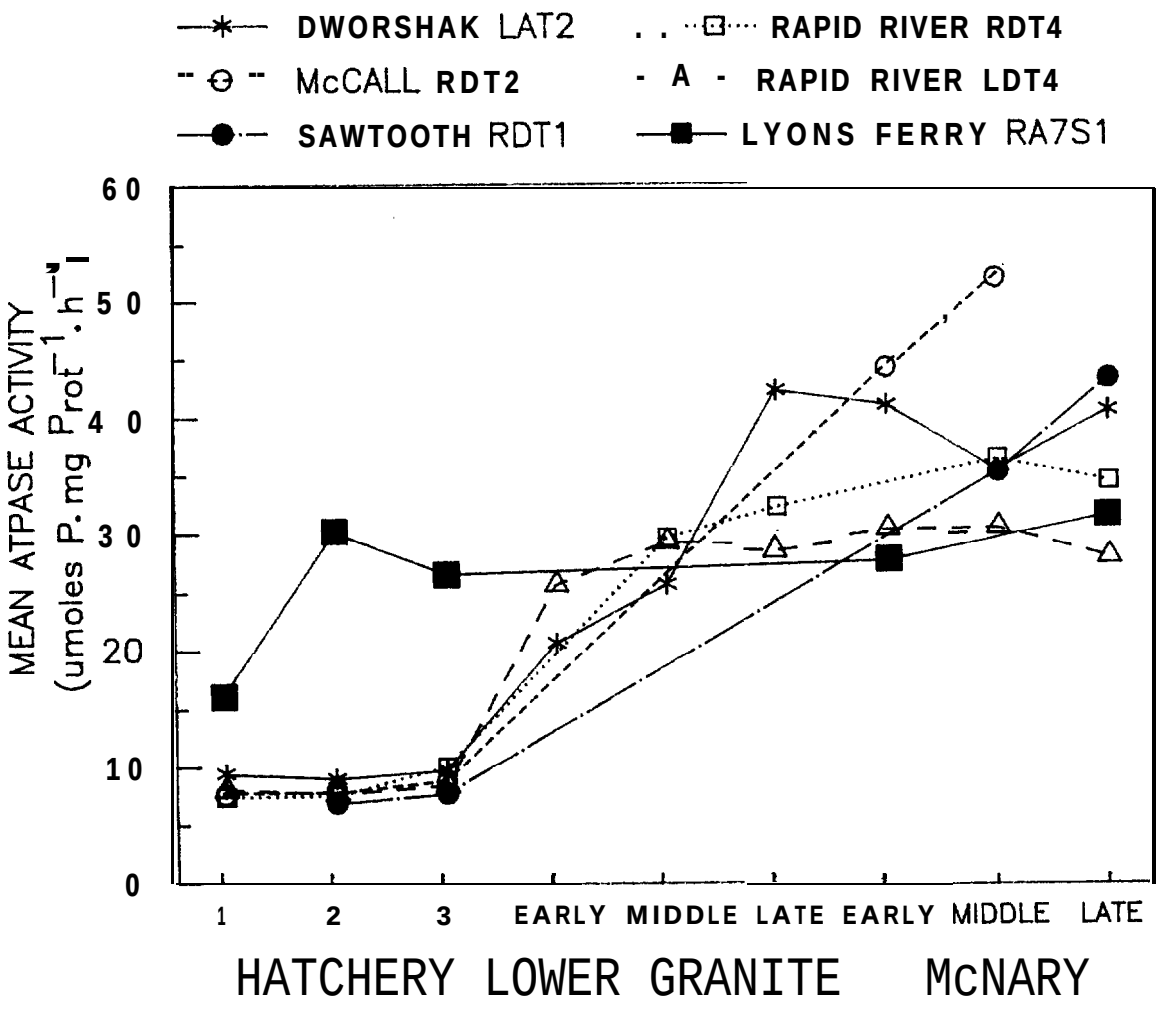


Figure 16. Mean gill Na^+-K^+ ATPase activity of spring and summer chinook salmon from Snake River hatcheries, spring 1988. Samples were collected one month, two weeks, and shortly before release (1,2,3 respectively) and again at the early, middle, and late portions of the migrations past Lower Granite and McNary dams.

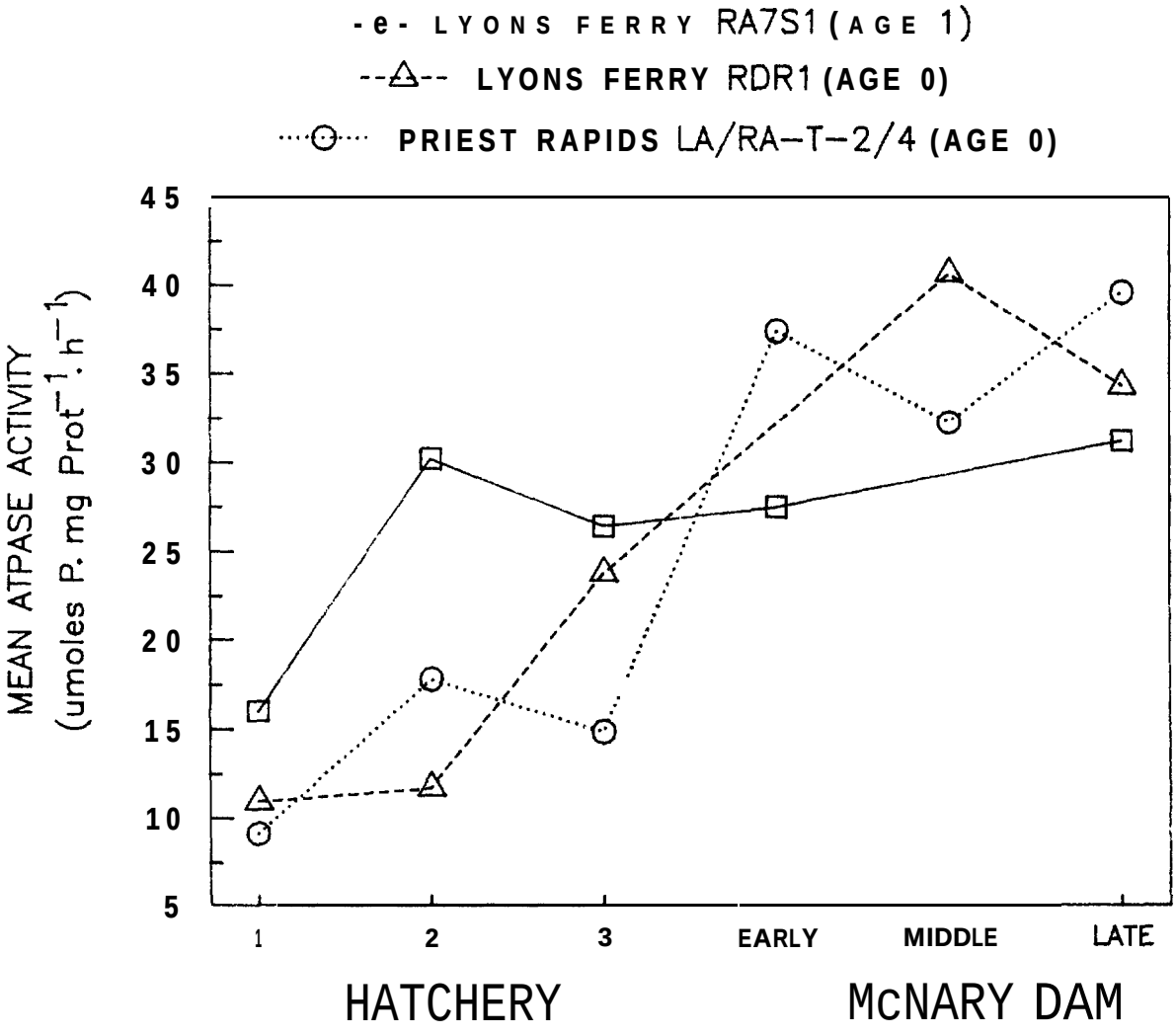


Figure 17. **Mean gill** Na^+**-K+ ATPase activity** of fall chinook salmon from mid-Columbia and lower Snake River hatcheries, spring **1988, Samples were collected one month, two weeks, and shortly** before release (1,2,3 respectively) and again at the early, middle, and late portions of the migrations past McNary Dam.

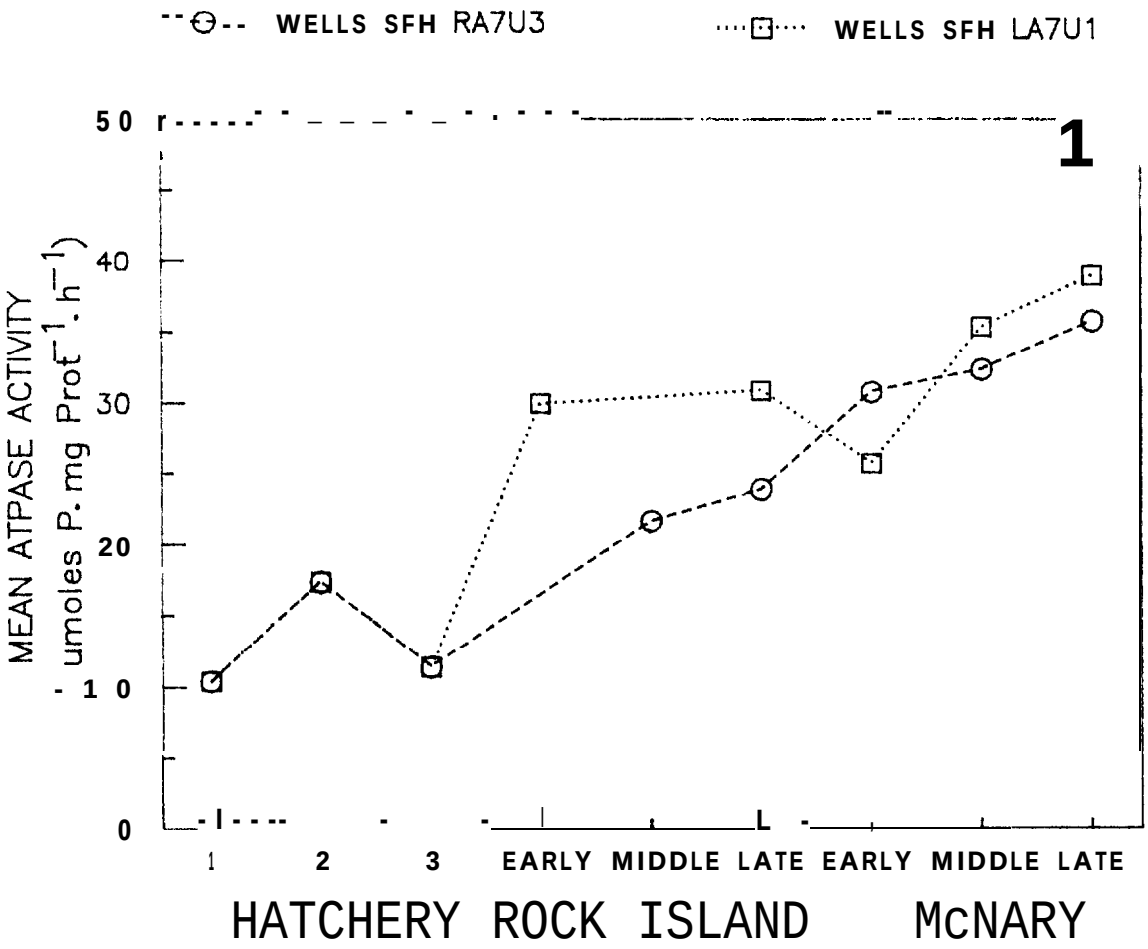


Figure 18. Mean gill. Na^+-K^+ ATPase activity of steelhead trout from Wells SFH, spring 1088. Samples were collected one month, two weeks, and shortly before release (1,2,3 respectively and again at the early middle, and late portion:? of the migrations past Rock Island and McNary dams.

Wells SFH were reared in the same pond, and were therefore sampled as one group prior to branding at the hatchery. At Rock IsLand Dam, the Wells group released in the Sinilkameen River (LA-7U-1) had much higher ATPsse activity than the group released in the Methow River (RA-7U-3). Steelhead released in the Similkameen River migrated a longer dis tance prior to passing Rock Island Dan and had been in the river longer than fish released in the Methow River. As the steelhead from Wells SFH migrated past McNary Dam the differences in qill ATPase were small.

Mean ATPase activities of all steelhead groups released in the Snake River basin were generally increasing as fish passed Lower Granite Dam (Figure 19). At Lower Granite Dam, steelhead from Hagerman NFH and Niagara Springs SFH had the highest mean ATPase activities 0f any steelhead group sampled from the Snake River. Only .steelhead from Dworshak and Lyons Ferry were recovered at McNary Dam in sufficient numbers for adequate sampling. The ATPase activity of both groups was relatively constant as the migration proceeded past McNary Dam, suggesting the ATPase increase associated with smoltification was completed

Gill ATPase activities of yearling spring chinook and steelhead increased sharply after release from the hatchery, but leveled off at about 30 umoles•P ● mg $Prot^{-1}$•h^{-1} dfter 15 to 20 days of in-river migration (Figure 20). These patterns of increases in ATPase activity are alike, suggesting post-release SmoLtification may proceed similarly in both species .

Plasma thyroxine levels of mid-Columbia chinook salmon were variable (Figure 21). Prior to release, fish at Leavenworth NFH and Rinqold SFH exhibited a peak in thyroxine whereas those at Entiat NFH and Winthrop NFH did not. Thyroxine Levels in fish recovered at Rock Island and McNary dams were higher than at release, but no trend was evident.

Most chinook salmon groups at Snake River hatcheries showed a surge in mean thyroxine values two weeks prior to release (Figure 22). Thyroxine levels after release were characterized by an increase followed by a gradual decrease. This trend appears to be associated more with date than with collection site (Figure 22b). Thyroxine levels of aqe zero chinook salmon from Lyons Ferry SFH and Priest Rapids SFH were relatively low at the hatchery and at McNary Dam, while yearling fall chinook salmon from Lyons Ferry SFH showed a large increase in plasma thyroxine after release (Figure 23).

Steelhead at Wells SFH showed a surge in plasma thyroxine prior to release, hut by the time of release Levels were quite low (Figure 24). Fish collected during the migration had pLasma thyroxine concentrations slightly above those at release. At Rock Island Dam, the group that had been liberated at the Methow River (RA-7U-3) had h ighe r thyroxine levels than those released at the Similkameen River (LA-7U-1), but the Levels of both groups were similar at McNary Dam.

Three of the five groups of steelhead sampLed prior to release in the Snake River basin had similar patterns of thyroxine Levels (Figure 25). At Hagerman NFH, Irrigon SFH, and Niagara Springs SFH thyroxine levels were relatively low prior to release. Among these three groups, steelhead **arriving early in the migration past** Lower Gran ite Dam exh ibited a peak in plasma thyroxine. This appears to be as soci a t ed wi th the new moon on 15 May and/or increased flows at Lower Granite Dam (Figure 26) .

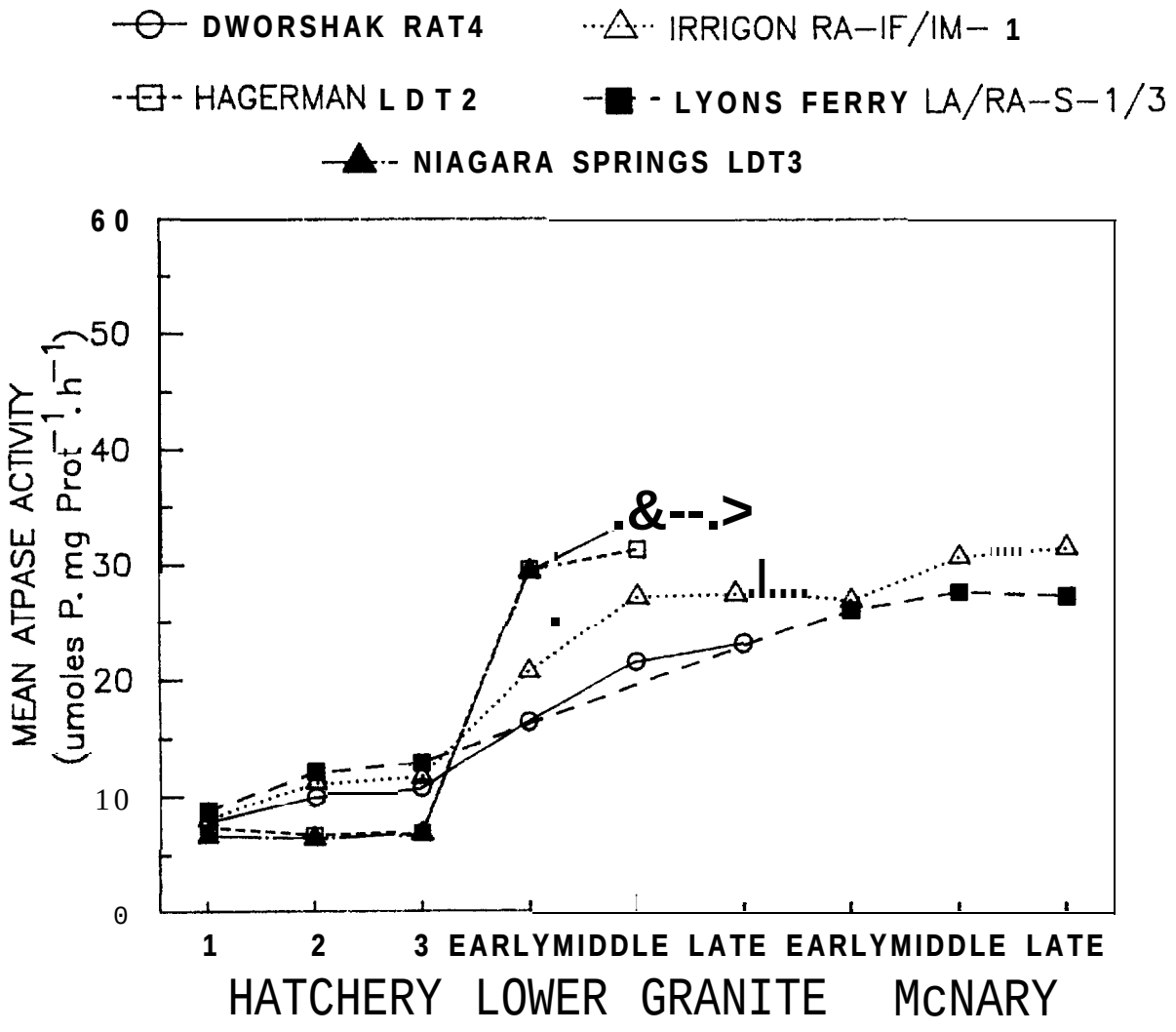


Figure 19. Mean gill Na^+-K^+ ATPase activity of steelhead trout from Snake River hatcheries, spring 1988. Samples were collected one month, two weeks, and shortly before release (1,2,3 respectively) and again at the early, middle, and late portions of the migrations past Lower Granite and McNary dams.

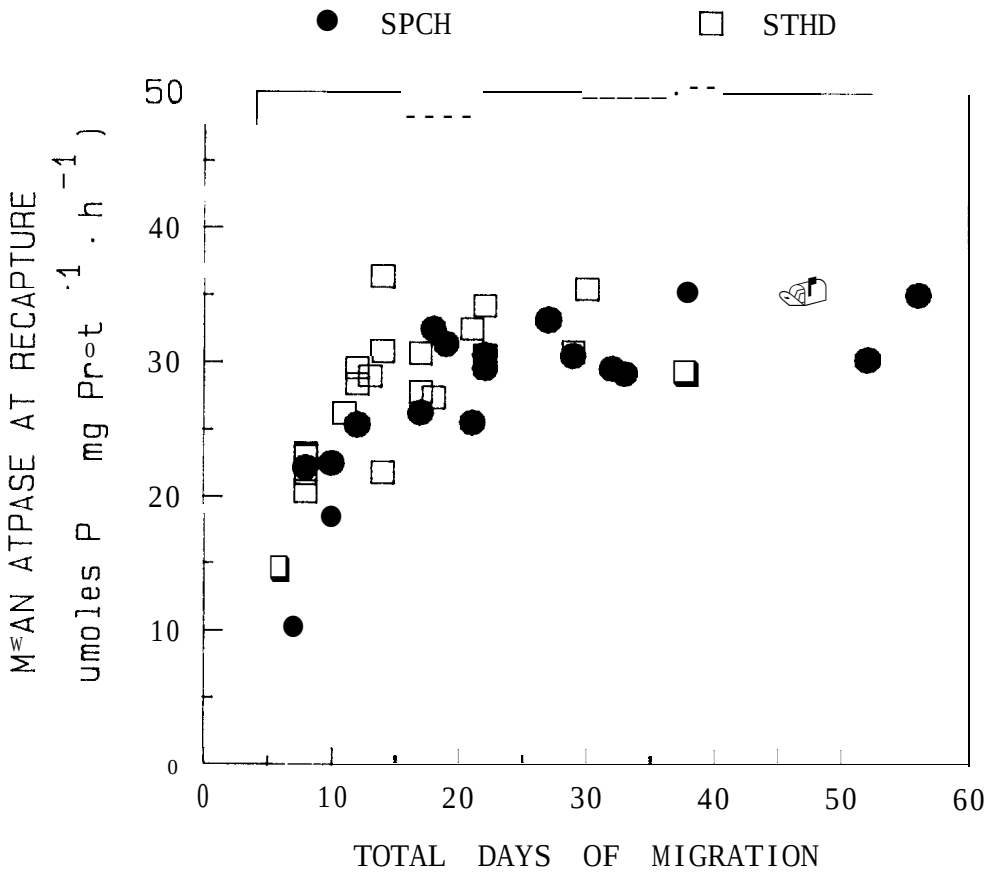


Figure 20. Changes in mean ATPase activity of spring chinook salmon and steelhead trout as a function of days of river migration, 1987 and 1988.

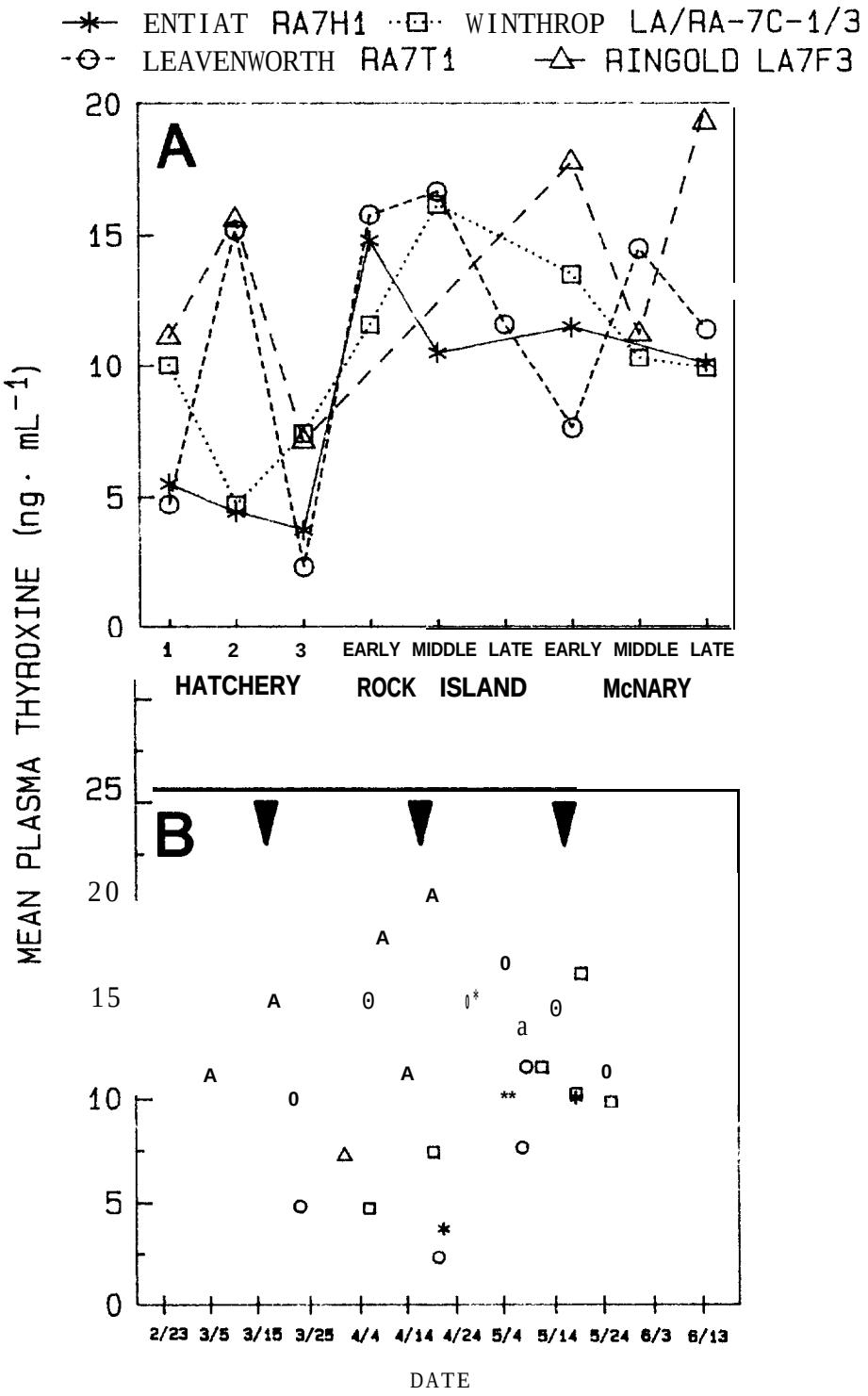


Figure 2 1. Mean plasma thyroxine (T_4) of spring chinook salmon from mid-Columbia River hatcheries by sample site (A) and date of collection (B), spring 1988. Arrowheads indicate new moons.

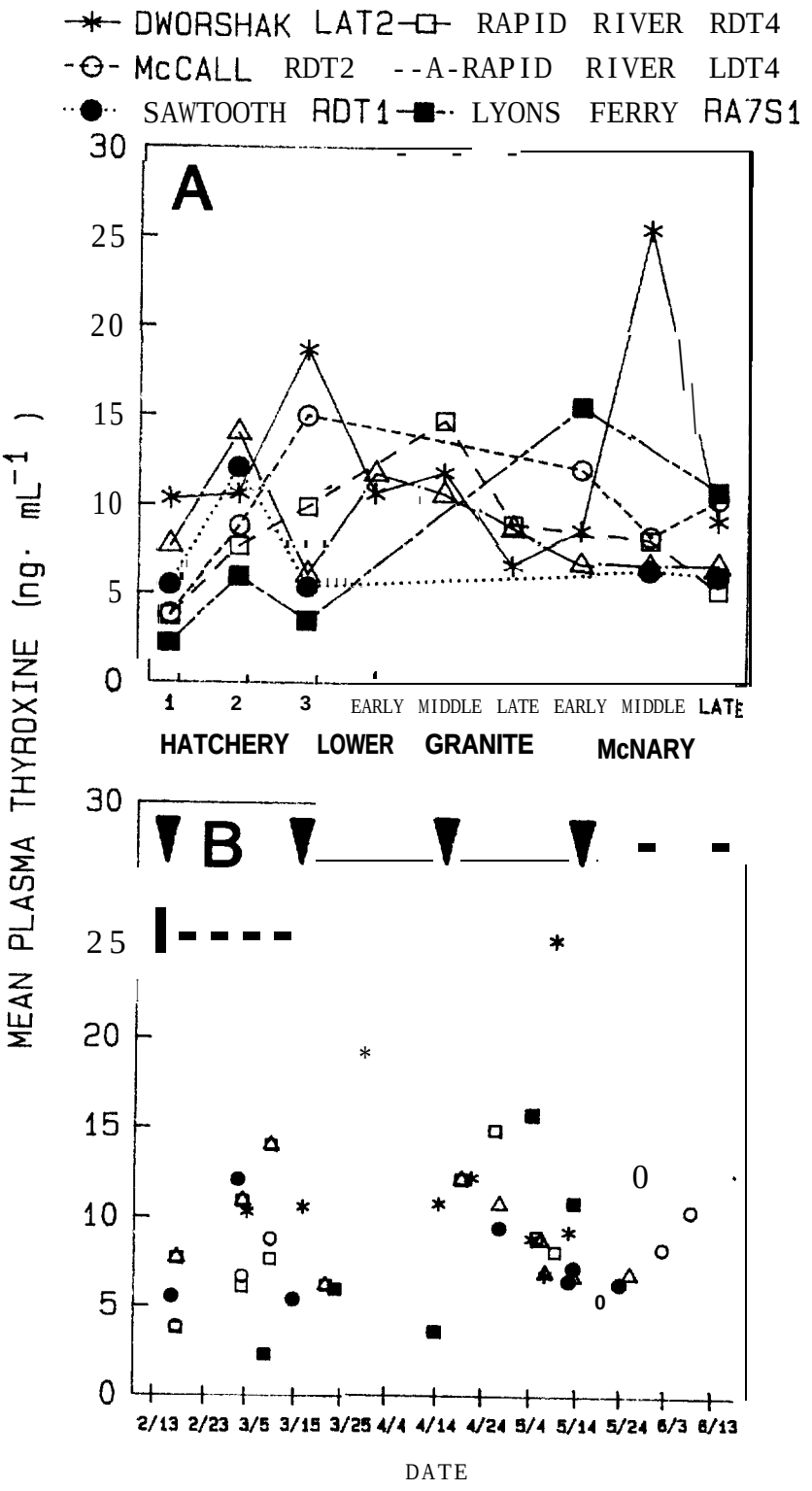


Figure 22. Mean Plasma thyroxine (T_4) of spring chinook salmon from Snake River hatcheries by sample site (A) and date of collection (B) in spring 1988. Arrowheads indicate new moons.

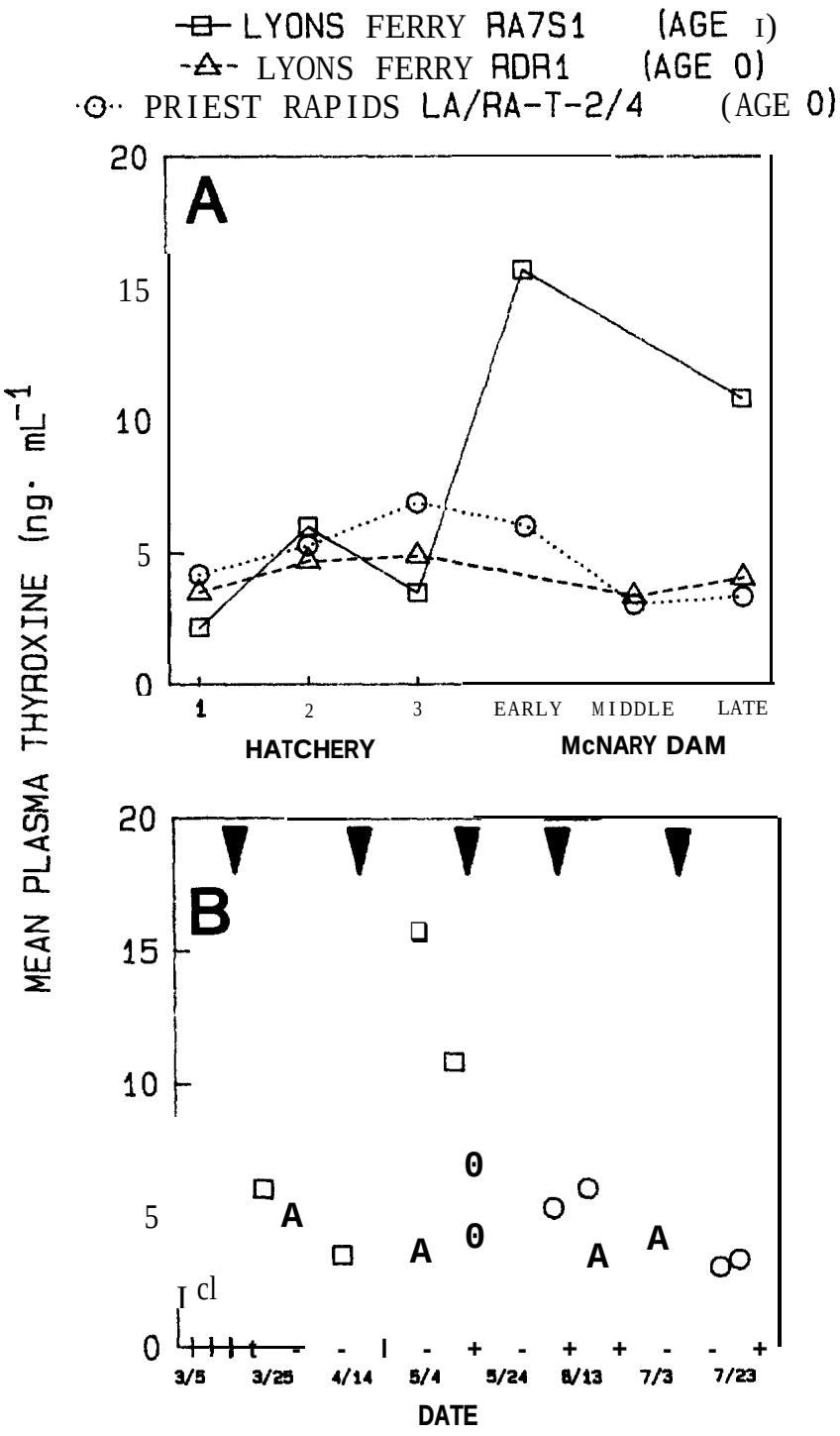


Figure 23. Mean plasma thyroxine (T_4) of fall chinook salmon by sample site (A) and date of collection (B), spring 1988. Arrowheads indicate new moons.

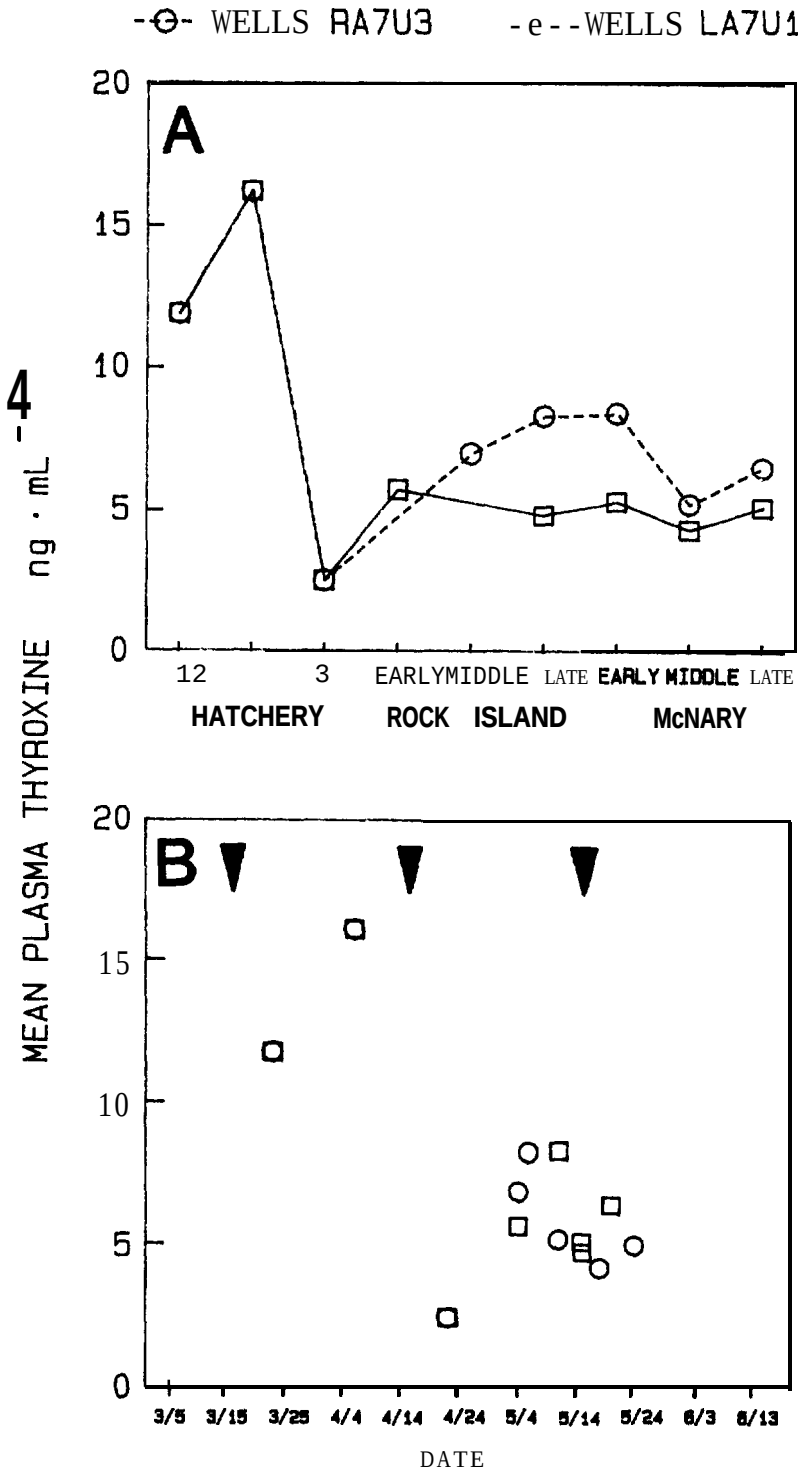


Figure 24. Mean plasma thyroxine (T_4) of steelhead trout from Wells SFH by sample site (A) and date of collection (B), spring 1988. Arrowheads indicate new moons.

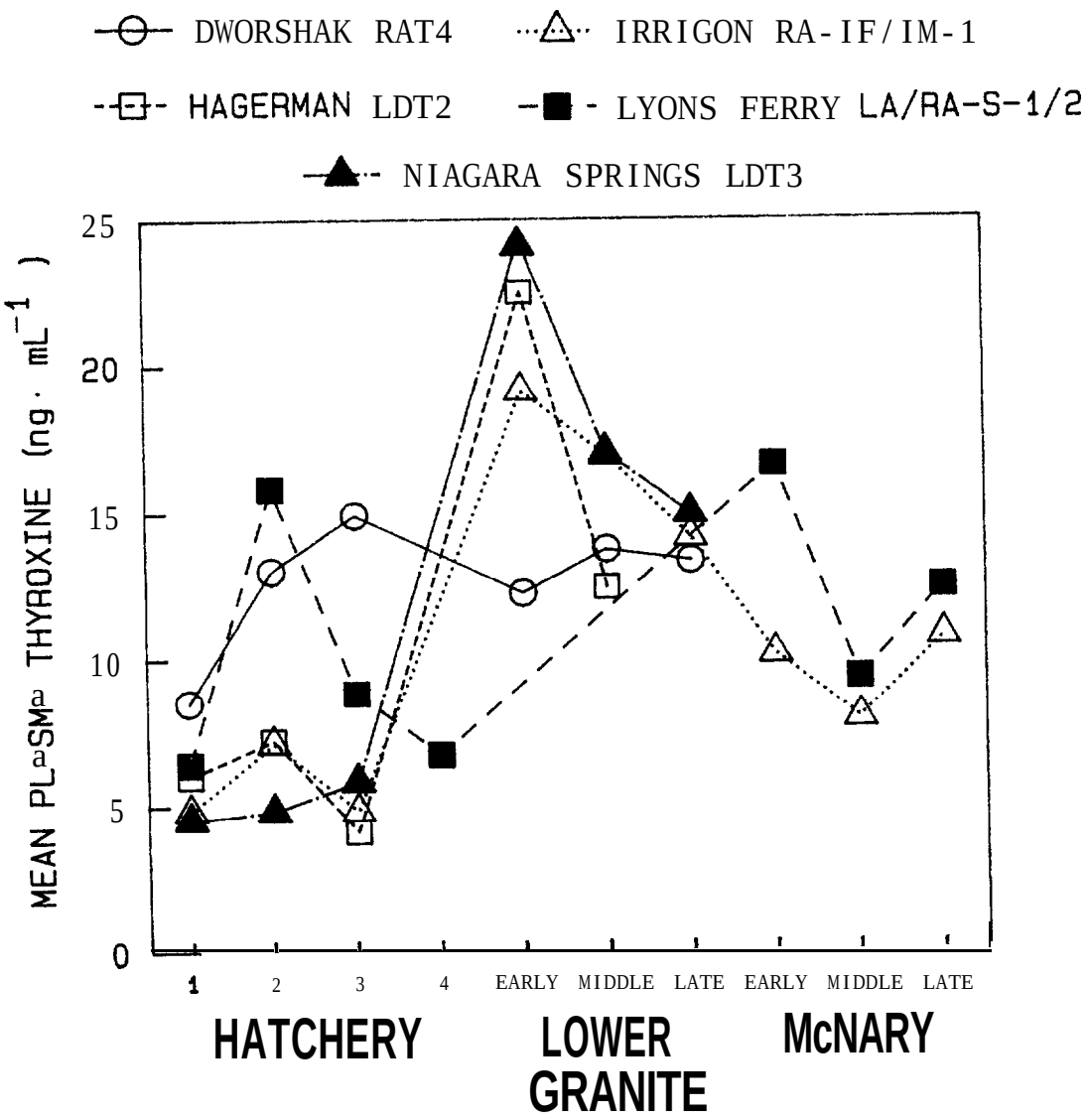


Figure 25. Mean plasma thyroxine (T_4) of steelhead trout from Snake River hatcheries by sample site, spring 1988.

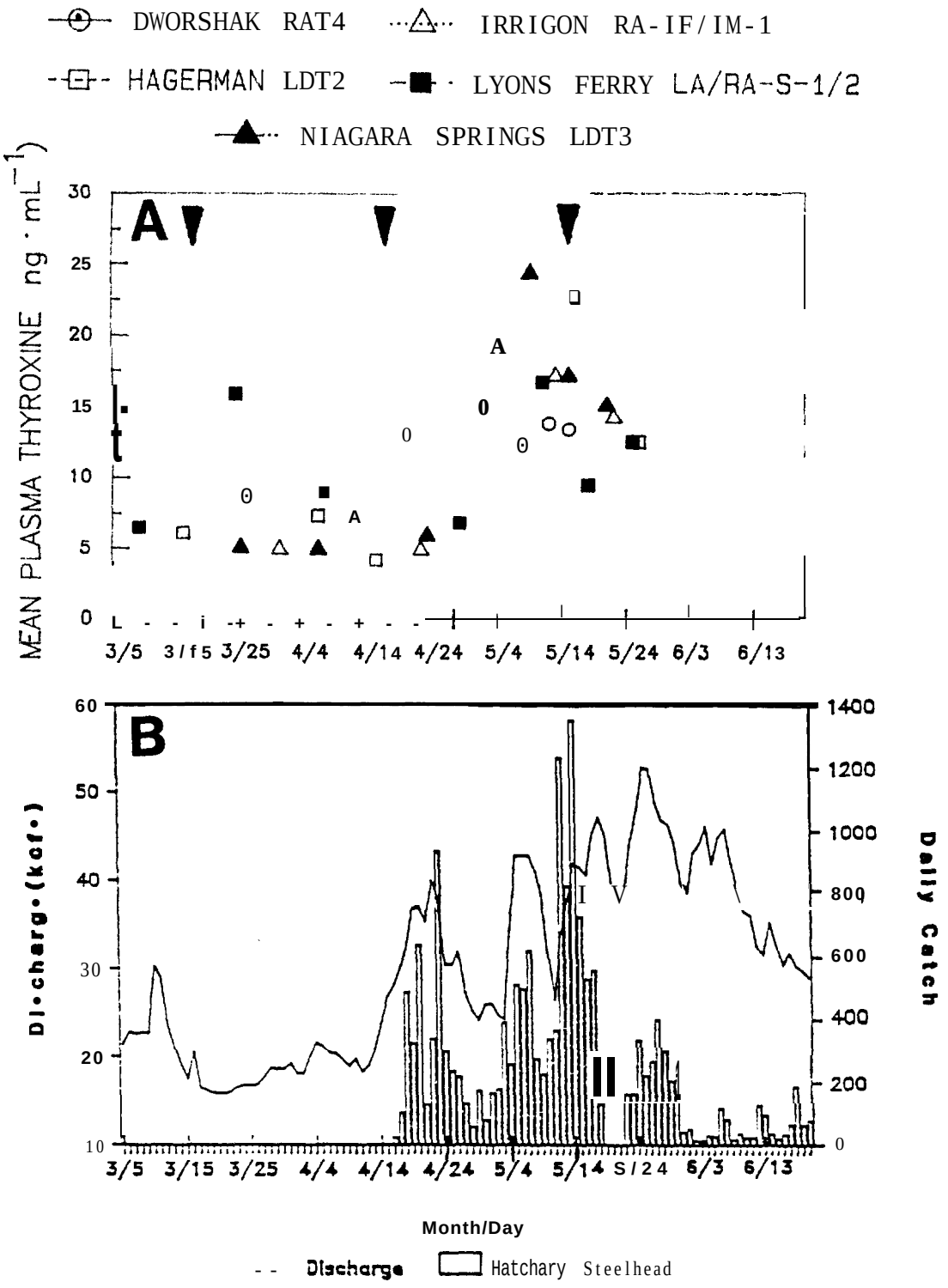


Figure 26. Mean plasma thyroxine (T_4) of steelhead trout from Snake River hatcheries by date of collection (A), and Snake River river trap daily catch of hatchery steelhead overlaid by Snake River discharge at the Idaho Department of Fish and Game (IDFG) Anatone gauge (B) (reprinted with permission from IDFG), spring 1988. Arrowheads indicate new moons.

Mean guanine levels and the mean guanine to hypoxanthine ratio (Gn/Hx) in spring chinook salmon from Winthrop NFH increased steadily as the fish migrated past McNary Dam increasing 38% and 31%, respectively (Figure 27). While hypoxanthine levels changed little during this period, the levels of guanine increased resulting in an increase in the ratio of guanine to hypoxanthine (Appendix 18). The increase in these measures of purines closely paralleled the changes in gill ATPase activity of fish sampled concurrently.

A diagramatic presentation was used to illustrate observed changes in average body shape or form during the migration from release sites to recapture facilities. Spring chinook salmon from Sawtooth SFH and steelhead trout from Hagerman SFH were used as examples from data collected in spring, 1988. Fish from Sawtooth SFH were sampled at the hatchery and McNary Dam. Steelhead from Hagerman were examined at the hatchery and at Lower Granite Dam. Since the differences in size of fish at the hatchery and collection facilities was usually less than 10 mm, a mean intermediate fork length was used for the average body shape.

Spring chinook salmon exhibited a decrease in body depth during the migration period and changes in form of the head and caudal peduncle. Line lengths in figure 28a describe lines ranging from number one in the head region to 33 in the caudal peduncle. The predicted line segments were used to illustrate the average form of the fish at the hatchery (dashed line) and at McNary Dam (solid line) (Figure 28b). In this case the gap between the dashed and solid line represents the change in average form. The decreases in body depth after migration to McNary Dam are indicated by the smaller predicted lengths of lines 12 to 21 (Figure 28a).

Steelhead also decreased in relative body depth during the downstream migration. There was a notable difference in the head region and in the caudal peduncle at the McNary Dam compared to fish at the hatchery (Figure 29). Principle component analyses are being used to determine if changes in shape can be detected when the within-group size effects are removed.

Discussion

The measures of smoltification, gill ATPase, thyroxine, and morphology were, like the measures of stress, interpreted by comparing the results for all groups. The post-release increase in ATPase activity appears to be a time-dependent development associated with smoltification (Figure 20). Inasmuch as this development was time related, fish migrating a relatively short distance arrive at a monitoring facility with relatively low ATPase activities. Conversely, fish that migrate longer distances often arrive at downstream dams with relatively high ATPase values. For example, at release, fish at Ringold SFH had a relatively high "hatchery" ATPase value of 13.8 umoles $P \cdot mg\ Prot^{-1} \cdot h^{-1}$, but at McNary Dam these fish had relatively low "in-river" ATPase activity of

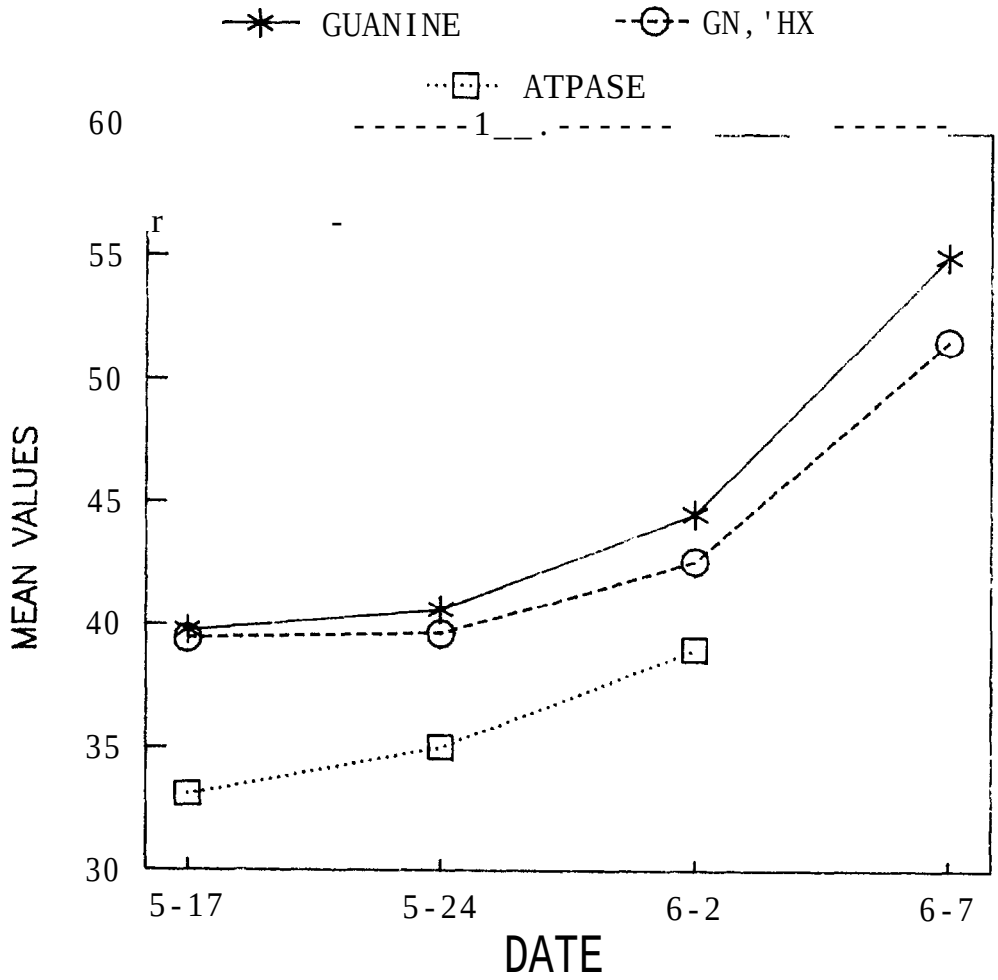


Figure 27. Mean Guanine (mg•g tissue-'), Guanine - Hypoxanthine ratio times 10 (GN/HX), and Gill ATPase activity (umoles P•mg Prot^{-1}• hr^{-1}) of spring chinook salmon from Winthrop NFH collected at McNary Dam, spring 1988.

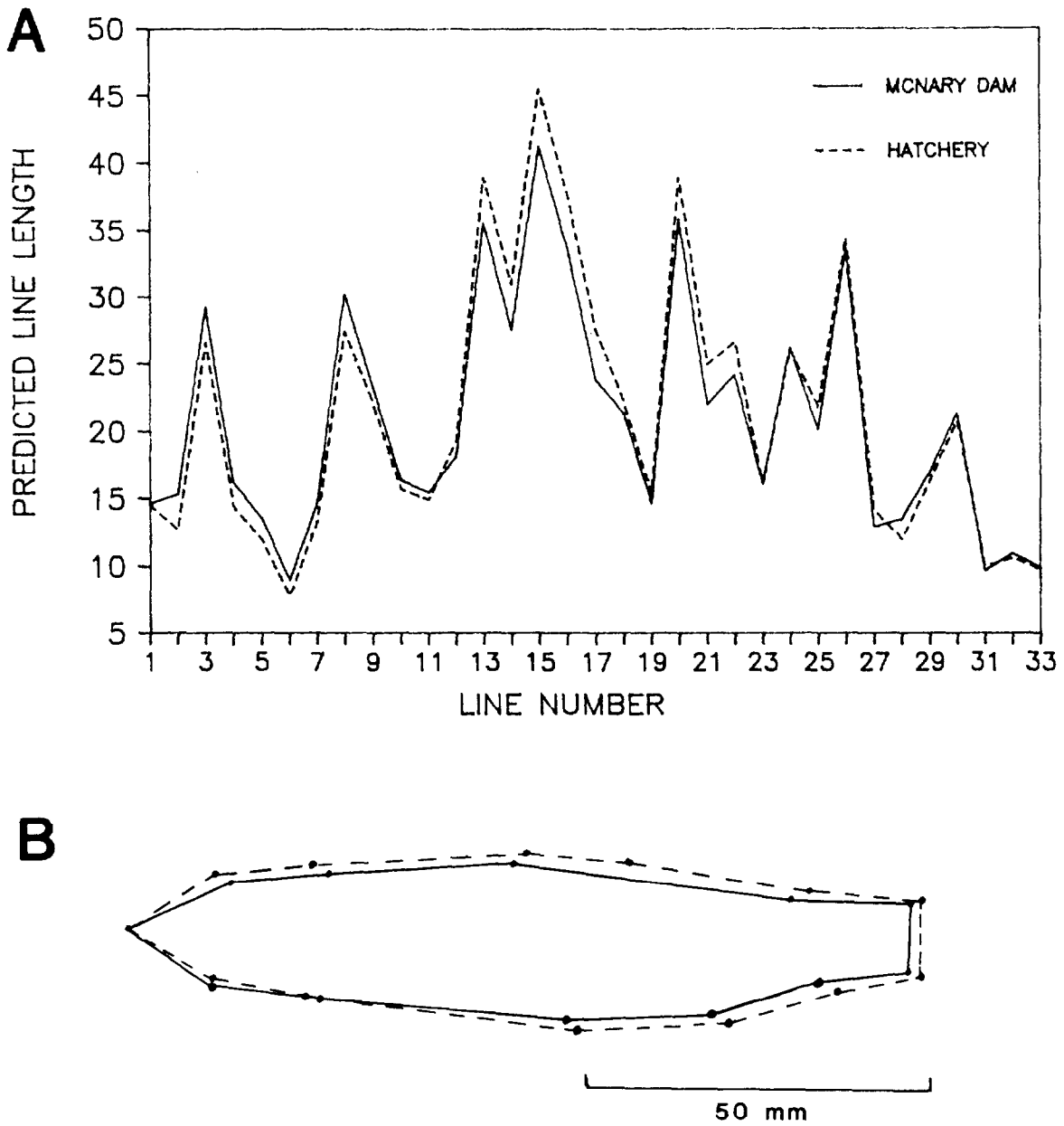


Figure 38. Predicted line lengths for standard body size (130 mm fork length) of spring chinook salmon at Sawtooth SFH and at McNary Dam (A) and reconstructed form of spring chinook salmon at standard body size. Dashed line represents average form at hatchery; solid line represents average form at dam (B).

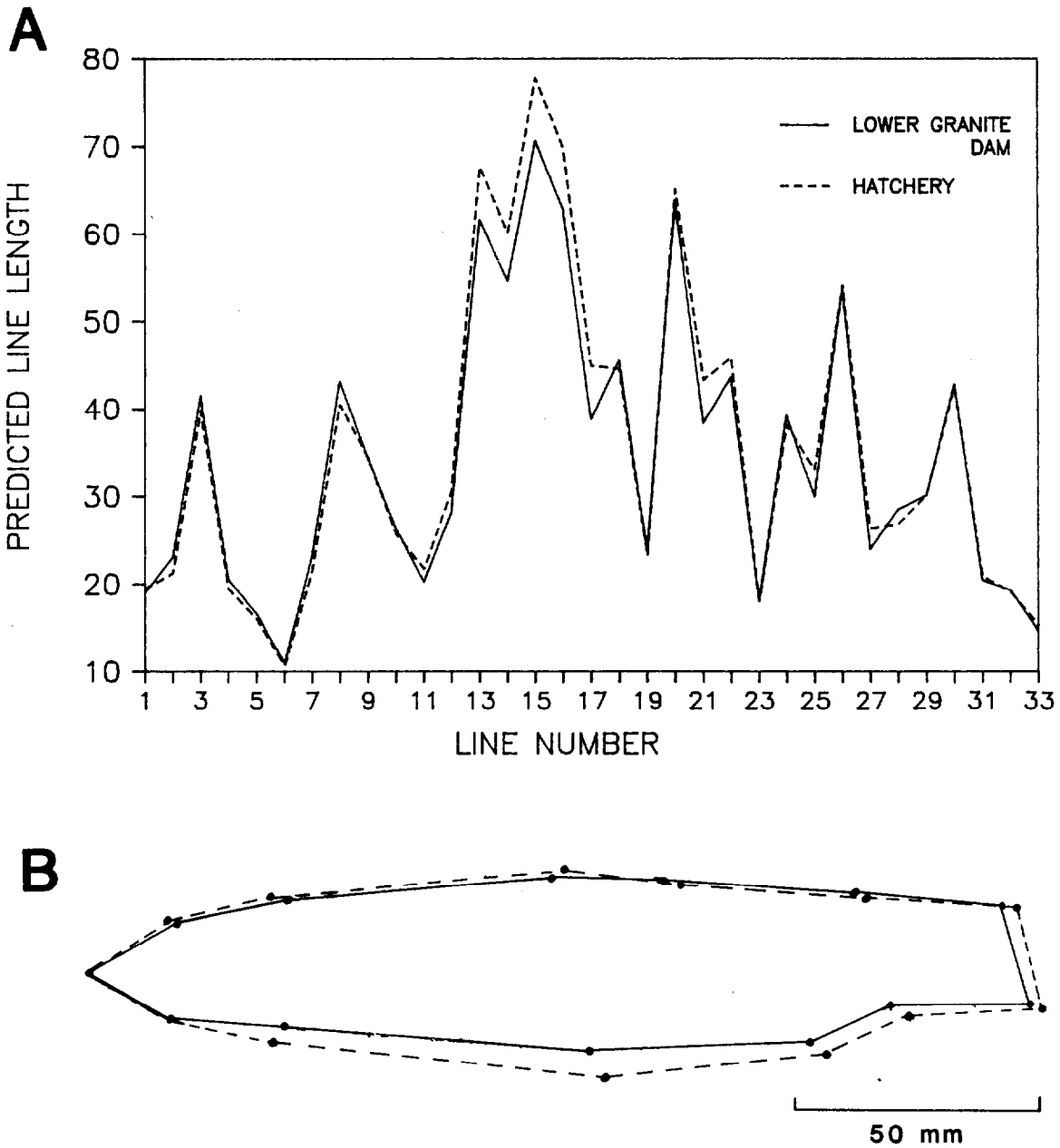


Figure 29. Predicted line lengths for standard body size (220 mm fork length) of steelhead at Hagerman SFH and at Lower Granite Dam (A) and reconstructed form of steelhead at standard body size. Dashed line represents average form at hatchery; solid line represents average form at dam (B).

22.4 compared to "in-river" values of 27.8 to 33.1 for mid-Columbia spring chinook salmon migrating greater distances. The other measures of smoltification, morphology and thyroxine levels, generally support the in-river development hypothesis.

Thyroxine dynamics may cause difficulty in using it as a measure of smoltification. Dickhoff et al. (1982) demonstrated that the percentage of thyroxine peak was correlated with the proportion of surviving hatchery SMOLTS after 6 months in seawater net-pens. Plasma thyroxine surges have been shown to be associated with both flows and lunar cycles, but little data is available on migrants in large river systems (Mason 1975; Grau et al. 1982; Youngson et al. 1986). Specker et al. (1984) proposed that changes in thyroxine kinetics reflect an increased requirement for thyroid hormones during periods of rapid development. In our study peak levels may have been associated with the lunar phase and/or peaks in flow during which numbers of migrating fish peaked.

If post-release smoltification is accompanied by increased behavioral disposition to migrate, then differences in migration rates in upstream index reaches nay be a result of the combination of disposition to migrate and flow. However, as fish approach full development their extent of smoltification is likely to play a diminished role and flow is likely to act as a determinant of migration rate to a greater extent. Data from only 1988, with two species, chinook salmon and steelhead, and two reaches, lower Snake River and mid-Columbia River, is not sufficient for further analysis of the role smoltification might play in migration rate. When 1987 and 1988 data for steelhead from the mid-Columbia and Snake rivers was pooled, the correlation between migration rate and flow at Ice Harbor and Priest Rapids Dams was r = 0.92, N = 15. However, the correlation between gill ATPase and migration rate was r = 0.80 when ATPase at the time of release from the hatchery was used as a single measure of smoltification. Due to the small sample size, several other weak correlations with physiological attributes are probably spurious, even though they are biologically reasonable.

BKD IN CHINOOK SALMON

Methods and Materials

The incidence of BKD in spring chinook salmon from Sawtooth State Fish Hatchery (SFH), and Dworshak, Entiat, and Winthrop National Fish Hatcheries (NFH) was estimated. Kidney and spleen samples were collected at the hatcheries and at Rock Island Dam (Entiat NFH, Winthrop NFH), Lower Granite Dam (Dworshak NFH, Sawtooth SFH), and McNary Dam (all groups). Samples were stored in vials in liquid nitrogen until they reached the laboratory, where they were stored in a freezer at - 78'C.

Tissue samples were mashed and smears analyzed using the Fluorescent Antibody Test (FAT) with a 100 field count (McDaniel 1979). Samples were arbitrarily divided into one of four categories depending on the number of BKD conjugates as follows: negative, none found; low, 1-15; medium, 16-90; and high, greater than 90.

The same material was analyzed for antigen levels with the Enzyme-Linked Immunosorbent Assay (ELISA) using the method of Pascho et al. (1987). The antibody/conjugate was obtained from Kirkeqaard and Perry Laboratories, Inc. ELISA results were considered positive for BKD when optical densities were above 0.073. Samples determined to be positive using the ELISA were arbitrarily divided, based upon the optical density (OD), into three categories: low (0.074 to 0.1201, medium (0.121 to 0.280), and high (0.281 and over).

Results

The prevalence of BKD as determined by FAT and ELISA for groups of fish from Dworshak NFH, Sawtooth SFH, Entiat NFH, and Winthrop NFH are summarized in Table 3. Prevalence of BKD at the hatchery as determined by ELISA varied from 53% at Dworshak NFH to 91% at Sawtooth SFH. Downstream at either Lower Granite or Rock Island dams, the proportion of fish with BKD increased above that at the hatchery. Prevalence reached nearly 100% for Winthrop stocks at Rock Island Dam. At McNary Dam, percentage of BKD positive fish was roughly comparable to those at Lower Granite or Rock Island dams. Therefore, no significant change in prevalence of BKD was noted between the upstream dams and McNary.

Samples determined to be positive using the ELISA can provide additional information by examining the number with high antigen levels. Fish with hiqh antigen levels ranged from 1 to 13% of the populations at the hatchery. At downstream dams fish with high antigen levels ranqed from 1 to 33% of the marked populations (Table 4).

Differences in prevalence between early and late portions of the migration were insignificant, with the exception of the Winthrop group. Winthrop smolts showed an increase in prevalence later in the run at McNary. The prevalence as determined by ELISA increased from 76% early in the run to 94% and 100% in the middle and late segments of the migration, respectively. Visual examinations indicated the percentage of fish from Winthrop NFH with lesions in the kidney increased from 0, to 13, to 44% in the early, middle, and late segments of the migration, respectively. Winthrop NFH fish differed from fish at the other hatcheries in that they had the highest percentage of fish (13%) in the high antigen level category compared to 1 to 7% for the others (Table 4).

The sensitivity of the ELISA method was obvious since the prevalence of BKD reached nearly 100% in some groups. The prevalence of BKD according to ELISA was inconsistent with FAT results. FAT results were consistently lower than those of ELISA. For example, fish at Sawtooth

Table 3. Prevalence of BKD (%) in spring chinook salmon from five Columbia River hatcheries as determined by enzyme linked immunosorbent assay and fluorescent antibody test. The smolts were sampled at the hatchery and at downstream dams after release.

stock	SAMPLING SITE							
	Hatchery		Lower Granite		Rock Island		McNary Dam	
	ELISA	FAT	ELISA	FAT	ELISA	FAT	ELISA	FAT
Dworshak	53	40	74	38	--	--	56	23
Entiat	66	26	--	--	77	29	67	36
Winthrop	79	47	--	--	97	34	91	51
Sawtooth	91	11	Insufficient numbers recaptured.					

Table 4. Results of the Enzyme Linked Immunosorbent Assay for bacterial kidney disease in spring chinook salmon from four Columbia and Snake river hatcheries. Positive samples are divided into three categories based upon the optical density. Also presented are the sample sizes and the percent of visible lesions observed in the kidney.

Sample Site	Pos %	Pos (No.)	Low %	Low (No.)	Medium %	Medium (No.)	High %	High (No.)	N	% Lesions
Dworshak NFH	53	(52)	44	(43)	8	(8)	1	(1)	98	0
Lower Granite Dam	74	(60)	41	(33)	11	(9)	22	(18)	81	7
McNary Dam	56	(64)	44	(50)	5	(6)	7	(8)	115	5
Sawtooth SFH	91	(88)	66	(64)	18	(17)	7	(7)	97	0
Entiat NFH	66	(64)	53	(51)	12	(12)	1	(1)	97	0
Rock Island	77	(26)	68	(23)	9	(3)	0		34	0
McNary	67	(56)	62	(51)	5	(4)	1	(I)	83	0
Winthrop NFH	79	(77)	52	(51)	13	(13)	13	(13)	98	4
Rock Island	97	(69)	51	(36)	34	(24)	13	(9)	71	4
McNary	91	(122)	32	(43)	26	(35)	33	(44)	134	17

SFH had a 91% prevalence according to ELISA, yet had only an 11% prevalence according to FAT.

Closer examination of the optical density (OD) of individual samples from fish which had >90 bacteria/100 fields according to FAT had OD ranging from 0.075 to 2.475, with one sample listed as negative (OD = 0.070). Therefore, all but one of these heavily infected fish were detected by ELISA, indicating that the ELISA method was accurate. The difference appears to be due to the greater sensitivity of the ELISA method.

Discussion

A general increase in prevalence of BKD from the hatchery to the first downstream dam was observed. The results from fluorescent antibody tests do not show this increase, probably due to the lesser sensitivity of the method (Pascho et al. 1987; Rondorf et al. 1988). This increase may be due to biased sampling at the dams. Matthews et al, (1988) reported that the incidence of BKD was higher in guided than unguided smolts on three different sampling dates (n = 180 fish total) at Lower Granite Dam.

Matthews et al. (1988) also reported that at Lower Granite Dam, the incidence of BKD, as determined by ELISA, increased from 29.7% in early April to 68.7% in late May. A similar increase over time was observed this year at McNary Dam in fish from Winthrop NFH, consistent with 1987 results for Winthrop stock (Rondorf et al. 1988). FAT results from Entiat stock at McNary Dam also tend to support these observations. The results from groups with moderate infections do not show a relationship between time and prevalence of BKD. Only fish from Winthrop NFH, which had a high percentage of heavily infected fish, showed an increasing prevalence of BKD as the migration passed.

Prevalence of BKD in Winthrop NFH smolts at McNary Dam, as determined by ELISA, was much higher than that of last year (BKD prevalence (ELISA) of 20, 22, and 36% in the early, middle, and late portions of the 1987 migration, respectively). Our report presents, for the first time, proportions of BKD infected smol ts reaching nearly 100% in samples collected at Rock Island and McNary dams.

According to Pascho and Mulcahy (1987) the optical density (OD) of the ELISA is positively correlated with the number of bacteria. One would expect that kidneys with visible lesions whould have much higher optical densities than infected fish without lesions, hut this was not always the case.

PART TWO: DEVELOPMENT OF AN INDEX OF SMOLT CONDITION

A REVIEW OF INDICES

An index of smolt condition could be a useful tool in summarizing the many attributes of smolt condition collected by this and other studies. Such an index would be desirable in assessing the condition of fish during seaward migration to assist with management and evaluation of the Water Budget. Toward synthesizing monitoring information and developing such an index, the following is a brief review of the use of indices in other areas of fisheries science.

An index is often a derived variable such as an average, a weighted average, or one measurement divided by another (Pimentel 1979). This derived variable can be used to estimate parameters that are too difficult or costly to measure directly. For example, the morphoedaphic index uses a ratio of total dissolved solids and mean depth to estimate fish yield in lakes (Ryder et al. 1974). Rather than trying to sample an entire fish population or a significant subsample, measurement of the two variables provides a more practical means of estimating fish yield. For estimating fish yield in streams, several indices have been used (Fausch et al. 1988). These use a variety of mathematical approaches and are based on either: 1) drainage basin variables; 2) channel morphometry and flow variables; 3) habitat structure, biological, physical, and chemical variables; 4) a combination of variable types; or 5) weighted usable area.

In some cases, one variable can be measured and correlated with the desired parameter. For example, Markevich (1977) used percent body fat as an index of silverside (Atherina mochon pontica) survival through the winter. Crowing counts of pheasants along transects to estimate abundance is another example of a one-variable index.

Sometimes the desired parameter can not be measured at all, but trends between years or days can be evaluated. The fish passage index for example (McConnaha 19851, does not estimate total numbers of smolts passing a given dam, but is useful for comparing size of the outmigration between years.

Simple linear regression is often used in indices where changes in the measureable variable X reflect changes in Y, the dependent variable to be estimated. For example, an increase in deer fecal pellet counts indicated a proportional increase in the population of deer. Since the relationship between X and Y is not always linear, exponential relationships can be transformed into straight lines by using logarithms.

Using multiple linear regression, inclusion of several independent variables improves the prediction equation. For example, independent habitat variables such as overhead and instream cover, stream order, and substrate were used by Hendrickson and Doonan (1972) and Fraley and Graham (1981) to predict the numbers of trout in a stream. Combining several

variables in an index can be a useful tool. Harris (1975) however, cautions that information about a variable's contribution to the regression coefficient of the equation is only provided within the context of the other variables. Various methods exist for selecting variables used in the regression models. For example, Lohr et al. (1988) used stepwise regression to identify significant variables that were used to develop an index of survival for patients with acute renal failure.

Principal components analysis (PCA) is a tool used to analyze data from a single sample of individuals from a single population and each individual is represented by a set of $p > 1$ measurements (Pimentel 1979). This method assumes that data for each measurement is normally distributed, but unlike multiple regression, independence of variables is not required. PCA can be used to select variables that can be used in aggregate (or individually) as an index. For example, Barber et al. (1981) used PCA to evaluate 17 variables used to estimate abundance of age-0 and age-1 coho salmon.

Factor analysis analyzes the intercorrelations within a set of variables. Like PCA, factor analysis can be used to identify variables that account for most of the variation of Y, the dependent variable. Harshbarger and Bhattacharyya (1981) measured 18 cover variables for trout and used factor analysis to boil these down to 6 variables that best described the data. Both the factors and the original variables were then used in multiple regressions to predict standing crop.

Indices which are derived variables have various disadvantages. Since errors of measurement are compounded, indices are less precise than single measurement variables. Also, distributions of indices are often far from normal. Atchley et al. (1976) noticed that when ratios were used to scale variables (e.g., to remove variation due to body size), the correlation between the ratio variable and the original scaling variable increased. Also, there was a spurious correlation between variables when ratios were compounded. The magnitude of the correlation increased as the coefficient of variation of the denominator increased. Principal components analysis is greatly affected when the data used is based on ratios or proportions rather than raw data. The problems of ratios may be circumvented by using a modification of ratios by Corruccini (1977).

For factor analysis, Pimentel (1979) cited several drawbacks pointed out by Blackith and Reyment (1971). The "bottom line" was that factor analysis consists of so many models and rotation schemes, that the outcome can nearly be controlled by the analyst who selects the model that best supports his preconceived conclusions.

Stepwise regression uses either a step-down or a step-up method to select variables that contribute most to the predictive equation. The two methods do not necessarily select the same variables. Also, both methods are prone to select variables that happen to predict well in a given sample. When tested, the variables that were "good" predictors may become "poor" predictors, particularly in small samples (Pimentel 1979).

Small sample size was a common problem in mathematical models reviewed by Fausch et al. (1988). They also noted that relatively precise models often lacked generality. (i.e., fewer than 20 degrees of freedom).

Fausch et al. (1988) reviewed 99 indices of standing crop of stream fish in which habitat variables were used to predict standing crop. Other problems noted by Fausch et al. (1988) were use of poor methods to chose the best model (index), not testing the index, and making unrealistic assumptions when making the estimates.

Levins (1966) outlined three desirable attributes of models: realism, precision, and generality. An ideal model or index would account for a large percentage of the variation in the desired parameter (e.g. standing crop) and give repeatable results. Skalski (1988) contends that an acceptable index should provide a measure of the sampling error associated with the index and provide the means to verify or adjust for violations in key assumptions of index calculations. Fausch et al. (1988) evaluated model quality based on the coefficient of determination, sample size, and degrees of freedom.

Ideally, an index of fish condition would provide a relative measure of smolt quality at release from the hatcheries, after migration through the sys terns, and among years with widely varying flow regimes. The index should be based on information that could be analyzed quickly. Fortunately the fish health and condition assessment procedures developed by Goede (1988) outline a clear methodology for evaluating fish health relatively quickly by simple observation. Both internal and external characteristics are examined and given a qualitative rating. This summary however, gives no single value for relative comparison so the results must be interpreted by a pathologist.

To be used as an index, the Goede method could be modified, Currently, some characteristics (thymus, mesentery fat, hind gut, and bile) are numerically rated and others are descriptive. The descriptive characters should be changed to a numerical rating in which a higher number indicates a graver condition. These modifications could take place in the computer program itself, Further modification may incorporate data on descaling currently collected at Columbia basin dams and some hatcheries. When the numerical values of all the characteristics are summed, the total would serve as an index of the health and physical condition of the fish. The higher the number, the poorer the condition of the population.

The underlying assumption of the index is that diseases manifest themselves in observable clinical signs. Another key assumption is that fish exhibiting a higher proportion of abnormal characteristics will have a lower probability of survival. Survival would be the ultimate measure of the merits of the fish condition index.

Survival of ocean-bound smolts is not only dependent upon disease factors, but smoltification factors as well (Dickoff et al. 1982). Conditions at hatchery facilities can suppress the smoltification process, compromising a smolt's ability to survive in salt water. To avoid compounding errors of measurement, a separate smoltification index may be developed, distinct from the condition index. Since mathematical tools such as principal component analysis are available to evaluate several variables at once, having separate indices to estimate fish health and smoltification is not a problem. Variables that could be used in development of the smoltification index include gill ATPaae, thyroid hormones, purines (silvering), and morphological variables.

Changes in smolt condition between sampling sites should be examined with caution. Logically, a greater proportion of sick fish than healthy fish will die between sites due to disease outright or to selective predation, negatively biasing an index value. Conversely, smoltification, stress, time, and temperature affect the course of a disease, causing latent infections to become clinical infections, positively biasing the index value. In addition, fish collection at the dams is biased hy selective capture of sick smolts (Park et al. 1986) and smolts with high gill Na+-K+ ATPase (Giorgi et al. 1988). If sick fish are not homogeneously distributed in front of each dam powerhouse, there may be additional sampling bias (Skalski 1988). Considering these biases, a fish health index would be most useful for evaluating year-to-year changes at the hatchery and downstream dams.

DATA COLLECTED IN 1988

Methods and Materials

Organosomatic examinations were conducted to monitor groups not examined by cooperators of the Augmented Fish Health Monitoring Program and to identify attributes useful in the assessment of condition among migrating smolts. The categories used in this assessment follow the method of Goede (1988) and are listed in Table 5.

Results

Organosomatic examinations using the approach of Goede (1988) provide a method to summarize easily observable clinical signs that are indicative of fish health or condition problems. In general, differences between groups were seen in the amounts of mesenteric fat, plasma protein, and condition factor (Appendices 19-22). Mean mesenteric fat of chinook salmon ranged from 0.7 to 1.8 on an arbitrary scale of 0 to 4. Ideally, a mean of 2, equal to 50% of the pyloric cecae covered, is a desirable amount before release (Goede, personal communication) although this was based on resident trout. Plasma protein ranged from 3.6 to 6.2 $g \cdot dL^{-1}$ and condition factors were between 1.02 and 1.09. The extent of thymic hemorrhage also showed minor differences among groups, particularly from Dworshak NFH. Fish from Entiat NFH had the lowest mesenteric fat and plasma protein, and also had the second lowest condition factor of any chinook group sampled at the hatchery. Steelhead trout had higher mesenteric fat contents than chinook salmon (range = 2.2 - 2.51, but other characteristics were similar (Appendices 23, 24). Fish from

Table 5. Categories used in the organosomatic assessment system of Goede (1988).

Length (L): Total Length in millimeters
Weight (W): Weight in grams

Condition factor (Kfl): $Kfl = W \times 10^5 \times L^{-3}$

Eyes: Normal (N), Exopthalmia (El, E2), Hemorrhagic (HI, H2), Blind (Bl, B2), Missing (Ml, M2), Other (OT)

Gills: Normal (N), Frayed (F), Clubbed (C), Marginate (M), Pale (P), Other (OT)

Pseudobranchs: Normal (N), Swollen (S), swollen & Lithic (S&L), Inflamed (I), Other (OT)

Thymus: No Hemorrhage (0), Mild Hemmorrhage (I), Severe Hemmorhage (2)

Mesentery fat: Internal body fat expressed with regard to amount present

0 - None
1 - Little, where less than 50% of each cecum is covered
2 - 50% of each cecum is covered
3 - More than 50% of each cecum is covered
4 - Ceca are completely covered by fat

Spleen: Black (B), Red (R), Granular (G), Modular (NO) Enlarged (E), Other (OT)

Hind Gut: No inflammation (0), Mild inflammation (l), Severe inflammation (2)

Kidney: Normal (N), Swollen (S), Mottled (M), Granular (G), Urolithiasis (U), Other (OT)

Liver:
A - Red
B - Light red
C - "Fatty" Liver; "coffee cream" color
D - Nodules in liver
E - Focal discoloration
F - General discoloration
OT- Other

Bile:
O - Yellow or straw color; bladder empty or partially full
1 - Yellow or straw color; hladder full, distended
2 - Light green to "grass" green
3 - Dark green to dark blue/green

Blood: Hematocrit - Volume of red blood cells (erythrocytes) expressed as percent of total blood volume. Centrifuged 5 min at 10,000 rpm.

Leucocrit - Volume of white blood cells (leucocytes) expressed as percent of total blood volume.

Plasma Protein - Amount of protein in plasma, expressed as gram percent (grams per 100 ml). Determined with hand-held protometer.

Irrigon SFH had the highest fat, condition factor, and plasma protein of the steelhead collected at the hatchery.

When examined at downstream collection facilities, changes from the fish condition at the hatcheries were noted in many groups. The most striking change was in the amount of mesenteric fat. Mean fat content of chinook salmon examined at Rock Island Dam was 0.8, lower than it had been at the hatchery (mean = 1.18; appendices 19-22). By the time these groups had migrated to McNary Dam, the fat content was at or near zero (mean = 0.12). Similar reductions in mesenteric fat occurred in steelhead from Irrigon SFH, with means at the hatchery and at McNary Dam equal to 2.38 and 0.29, respectively (Appendix 24).

Reductions in plasma protein and condition factor were also apparent. For example, mean plasma protein of mid-Columbia River chinook salmon was 4.8 $g \cdot dL^{-1}$ at the hatchery and 3.3 $g \cdot dL^{-1}$ at Rock Island Dam. The mean condition factor of these groups was 1.04 and 0.95 at the hatchery and Rock Island Dam, respectively. Plasma protein and condition factor data were not available for samples collected at McNary Dam. Generally, the gall bladders of fish collected at the dams were fuller and contained darker bile than fish collected at the hatcheries.

Discussion

Data from organosomatic examinations performed thus far have shown that the method of Goede (1988) was sensitive to physiological changes in fish due to smoltification and disease. Several organosomatic attributes exhibited post-release changes that may not be expected in the hatchery environment. For example, along with the in-river rise in gill ATPase activity is a concurrent decrease in mean percent body fat (Rondorf et al. 1985). Thus, the reductions observed in mesenteric fat, condition factor, and plasma protein were probably due to normal changes in fish physiology associated with in-river smoltification.

Anomalies of the spleen, kidney, and liver were noted in fish of several stocks, particularly in chinook salmon collected at McNary Dam. This was probably due to BKD. The prevalence of BKD (by ELISA) in chinook salmon at McNary Dam was nearly 100% in some stocks.

SUMMARY

1) Most groups performed adequately when subjected to a 30-s handling-stress challenge. Deviations from usual responses occurred when there were departures from protocols, disease problems at hatcheries, or long periods of trucking (7h). The handling-stress challenge test used in this study was useful in identifying groups with acute stress responses, but differences between moderately stressed groups were indistinguishable using this method. Since plasma cortisol and glucose levels are affected by smoltification, their interpretation as measures of stress of fish undergoing this process is difficult. Plasma chloride levels of smolts in freshwater are not affected by level of smoltification and may be better suited to this purpose.

2) Gill ATPase activities of most groups tested were relatively low at the hatchery and increased sharply for about the first 20 days of migration, after which they changed little. Decreases in body depth and changes in morphology of the head and caudle peduncle regions were also noted. Patterns of change in ATPase and body morphology were quite similar in spring chinook salmon and steelhead trout. Plasma thyroxine levels of most groups did not follow a discernable pattern. Thyroxine dynamics and a myriad of environmental influences make it a poor measure of smoltification of fish in reservoirs.

3) Results of the FAT and ELISA methods were inconsistent with one another. The ELISA method was much more sensitive. Prevalence of BKD in chinook salmon, determined using the ELISA method, was quite high in fish tested at some hatcheries and was generally higher among fish collected at the dams. In fact, the prevalence of BKD in some groups reached nearly 100% at Rock Island and McNary dams. Results from the FAT method indicated prevalences of about half this. There were no clear differences in prevalence of BKD between early and late migrants of groups with low to moderate infections of BKD, but in the group from Winthrop NFH, characterized by a large percentage of heavily infected fish, prevalence of BKD did increase as the migration passed McNary Dam.

4) Preliminary field work identified several parts of the organosomatic examination method of Goede (1988) to be of possible value in monitoring fish condition at hatcheries and dams, particularly if a numerical rating was used. Results of preliminary work indicated guanine levels of skin and scales, a measure of body silvering, were closely tied to gill ATPase activities of spring chinook salmon. Guanine may therefore be useful as an analytical method to aid in evaluation of visual observations of body silvering, a non-lethal measure of smoltification. Future index work should be aimed at further development of non-lethal measures of smolt development and condition.

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APPENDICES

Appendix la. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Entiat NFH branded RA-7H-1 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	CV	N	X	SD	CV	N
CORTISOL								
HATCHERY	17.5	10.8	62	20	124.8	38.0	30	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	99.9	19.3	19	14	100.5	20.9	21	11
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	134.8	4.0	3	16	128.4	5.6	4	15
TRUCK	(released at hatchery)							

Appendix lb. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Entiat NFH branded RA-7H-1 and sampled for gill NA^+-K^+ ATPase activity (umoles P_i •mg $prot^{-1}$•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Rock Island and McNary dams, spring 1988. Fish were released from the hatchery on April 21, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	CV	N
sample site = hatchery								
1	8.5	1.2	14	20	5.5	3.1	57	19
2	9.6	1.9	20	19	4.4	3.1	70	20
3	7.0	1.8	26	20	3.7	1.6	42	20
sample site = Rock Island Dam								
EARLY	9.4	3.2	34	20	14.8	13.4	91	21
MIDDLE	10.2	3.6	36	14	10.5	6.2	59	14
LATE	ND	ND	ND	ND	ND	ND	ND	ND
sample site = McNary Dam								
EARLY	25.8	6.0	23	18	11.5	6.1	53	16
MIDDLE	ND	ND	ND	ND	ND	ND	ND	ND
LATE	29.8	11.6	39	5	10.1	3.3	33	5

Appendix 2a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Leavenworth NFH branded RA-7T-1 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	7.4	3.9	53	20	88.9	26.6	30	19
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	99.1	19.3	20	10	124.3	38.7	31	15
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	133.5	4.4	3	13	129.0	5.1	4	20
TRUCK	(released at hatchery)							

Appendix 2b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Leavenworth NFH branded RA-7T-1 and sampled for gill NA^+-K^+ ATPase activity (umoles Pi'mg prot^{-1}•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Rock Island and McNary dams, spring 1988. Fish were released from the hatchery on April 20, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatcher								
1	9.8	1.8	19	20	4.8	2.6	55	19
2	10.7	1.4	13	20	15.2	11.3	75	20
3	7.6	1.8	23	20	2.3	1.1	50	20
sample site = Rock Island Dam								
EARLY	9.9	2.3	24	18	15.8	8.3	52	19
MIDDLE	18.4	3.6	20	15	16.7	13.4	80	13
LATE	19.6	6.8	35	24	11.6	7.9	68	23
sample site = McNary Dam								
EARLY	24.5	5.6	23	16	7.6	5.3	70	16
MIDDLE	29.5	7.5	25	14	14.5	7.7	53	13
LATE	43.6	5.2	12	20	11.4	5.6	50	19

Appendix 3a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV) and sample size (N) of spring chinook salmon from Ringold SFH branded LA-7F-3 and sampled for plasma cortisol (ng*mL-I), glucose (mg*dL-I), and chloride (meq*L'l) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	6.4	3.8	59	19	181.5	50.6	28	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	75.7	15.4	20	19	82.2	39.1	48	19
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	128.6	4.8	4	20	115.4	6.7	6	20
TRUCK	(released at hatchery)							

Appendix 3b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Ringold SFH branded LA-7F-3 and sampled for gill NA^+-K^+ ATPase activity (umoles Pi'mg $prot^{-1}$ hr^{-1}) and thyroxine (ng mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery on April 6, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	6.4	2.1	33	19	11.1	9.1	82	14
2	7.8	3.4	43	19	15.6	9.4	60	14
3	13.8	5.9	42	5	7.1	4.5	62	20
sample site = McNary Dam								
EARLY	18.4	8.6	46	19	17.8	7.1	40	20
MIDDLE	22.4	7.4	33	19	11.2	4.9	44	19
LATE	26.2	8.4	32	20	19.9	9.2	46	20

Appendix 4a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Winthrop NFH branded LA/RA-7C-l/3 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	CV	N	X	SD	CV	N
CORTISOL								
HATCHERY	8.7	5.1	59	19	142.1	43.3	30	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	110.0	15.2	14	16	103.2	35.7	35	17
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	128.8	3.9	3	19	120.9	7.5	6	18
TRUCK	(released at hatchery)							

Appendix 4b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Winthrop NFH branded LA/RA-7C-1/3 and sampled for gill NA^+-K^+ ATPase activity (umoles $P_i \cdot mg\ prot^{-1} \cdot hr^{-1}$) and thyroxine ($ng \cdot mL^{-1}$). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Rock Island and McNary dams, spring 1988. Fish were released from the hatchery on April 19, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	9.0	2.0	22	20	10.0	5.7	57	19
2	10.9	2.0	18	20	4.7	4.3	93	19
3	8.1	2.1	26	20	7.4	3.9	52	19
sample site = Rock Island Dam								
EARLY	22.8	4.8	21	18	11.6	5.3	46	18
MIDDLE	30.4	6.2	21	20	16.2	11.4	70	20
LATE	ND[1]	ND	ND	ND	ND	ND	ND	ND
sample site = McNary Dam								
EARLY	23.2	6.4	28	17	13.5	6.2	46	17
MIDDLE	33.1	7.4	22	20	10.3	4.6	45	20
LATE	33.0	4.8	15	14	9.9	4.2	42	14

[1] ND = No data

Appendix 5a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Dworshak NFH branded LA-T-2 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	17.0	11.6	68	19	117.9	30.3	26	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	106.8	20.6	19	18	130.1	32.5	25	16
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	133.4	3.4	3	20	125.0	5.1	4	20
TRUCK	(released at hatchery)							

Appendix 5b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Dworshak NFH branded LA-T-2 and sampled for gill NA^+-K^+ ATPase activity (umoles $P_i \cdot mg\ prot^{-1} \cdot hr^{-1}$) and thyroxine ($ng \cdot mL^{-1}$). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite and McNary dams, spring 1988. Fish were released from the hatchery on March 30, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	9.4	1.9	20	20	10.3	5.2	51	18
2	8.9	2.1	24	18	10.6	7.7	72	17
3	9.6	2.1	22	20	18.7	5.5	29	19
sample site = Lower Granite Dam								
EARLY	20.5	6.9	34	17	10.7	8.6	80	17
MIDDLE	25.5	7.2	28	26	11.9	5.5	46	25
LATE	42.1	15.2	36	20	6.7	3.8	56	19
sample site = McNary Dam								
EARLY	40.8	6.3	15	20	8.8	3.1	36	18
MIDDLE	35.2	7.2	20	4	25.5	12.9	50	4
LATE	40.3	8.8	22	24	9.2	5.3	57	24

Appendix 6a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of yearling fall chinook salmon from Lyons Ferry SFH branded RA-7S-1 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	21.4	11.3	53	19	179.6	45.7	25	19
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	98.6	12.3	12	19	128.6	20.3	16	19
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	119.2	4.8	4	19	115.4	3.2	3	19
TRUCK	(released at hatchery)							

Appendix 6h. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of yearling fall chinook salmon from Lyons Ferry SFH branded RA-7S-1 and sampled for gill NA^+-K^+ ATPase activity (umoles $P_i \cdot mg\ prot^{-1} \cdot hr^{-1}$) and thyroxine ($ng \cdot mL^{-1}$). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery on April 14, 1988.

	Na^+-K^+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	CV	N
sample site = hatchery								
1	16.0	6.2	39	20	2.2	I .o	46	16
2	30.2	6.2	20	20	6.0	3.4	57	20
3	26.4	5.8	22	20	3.5	3.7	106	20
sample site = McNary Dam								
EARLY	27.5	6.6	24	20	15.7	7.3	46	20
MIDDLE	ND[1]	ND	ND	ND	ND	ND	ND	ND
LATE	31.3	13.4	43	20	10.8	5.7	53	20

[1] ND = No data

Appendix 7a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of yearling summer chinook salmon, from McCall SFH branded RD-T-2 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	31.0	17.6	57	20	92 .o	24.1	26	19
TRUCK	119.2	32.3	27	I9	153.5	30.3	20	I9
GLUCOSE								
HATCHERY	92.7	31.2	34	20	108.7	13.5	12	I8
TRUCK	121.1	13.4	11	I9	135.5	21.0	I6	16
CHLORIDE								
HATCHERY	135.8	5.6	4	20	133.5	2.8	2	I9
TRUCK	133.9	3.5	3	I9	132.8	3.8	3	I8

Appendix 7b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of yearling summer chinook salmon from McCall SFH branded RD-T-2 and sampled for gill NA^+-K^+ ATPase activity (umoles Pi'mg $prot^{-1}$·hr^{-1}) and thyroxine (ng·mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary Dam, spring 1988. Fish were released from the hatchery on March 23, 1988.

	Na+-K^+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
I	7.6	1.6	20	20	3.8	4.1	107	19
2	7.8	I.7	22	I5	8.8	5.1	58	I4
3	8.6	I.8	21	20	15	6.8	44	18
sample site = McNary Dam								
EARLY	44.0	10.0	23	25	12.2	Il.7	96	25
MIDDLE	52.3	9.3	18	I9	8.3	4.2	51	I9
LATE	49.1	IO.5	21	4	IO.4	4.5	43	4

Appendix 8a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Rapid River SFH branded RD-T-4 and LD-T-4 sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
Brand RD-T-4								
CORTISOL								
HATCHERY	8.4	5.6	66	20	57.2	24.2	42	I9
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	89.3	17.6	20	I8	121.1	21.9	I8	19
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	130.2	8.6	7	20	123.4	4.5	4	I9
TRUCK	(released at hatchery)							
Brand LD-T-4								
CORTISOL								
HATCHERY	21.9	13.6	62	20	99.6	43.5	44	I9
TRUCK	99.1	41.2	42	20	183.2	34.7	I9	20
GLUCOSE								
HATCHERY	86.5	22.7	26	20	119.1	16.5	I4	19
TRUCK	142.6	48.5	34	20	131.8	44.8	34	20
CHLORIDE								
HATCHERY	129.6	4.3	3	20	124.2	II.8	IO	20
TRUCK	126.8	4.7	4	20	120.0	6.9	6	20

Appendix 8h. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Rapid River SFH branded RD-T-4 and LD-T-4 sampled for gill NA^+-K^+ ATPase activity (umoles P_i •mg prot^{-1} • hr^{-1}) and Thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite and McNary dams, spring 1988. Fish were released from the hatchery on March 23, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
Brand RD-T-4								
sample site = hatchery								
1	7.4	I.5	20	20	3.7	1.8	48	18
2	7.5	1.7	23	I8	7.7	5.3	69	18
3	9.9	1.3	13	20	9.9	5.3	54	20
sample site = Lower Granite Dam								
EARLY	ND	ND	ND	ND	ND	ND	ND	ND
MIDDLE	29.5	5.1	I7	I6	14.8	8.5	58	I6
LATE	32.1	8.0	25	20	8.9	4.8	54	20
sample site = McNary Dam								
EARLY	ND	ND	ND	ND	ND	ND	ND	ND
MIDDLE	36.2	7.3	20	I9	8.1	4.4	54	I4
LATE	34.2	7.8	23	20	5.3	3.8	72	20
Brand LD-T-4								
sample site = hatchery								
1	8.0	1.2	I5	20	7.7	3.8	49	I9
2	7.6	I.5	20	19	14.0	7.0	50	I4
3	8.3	2.3	28	19	6.1	3.6	59	20
sample site = Lower-Granite Dam								
EARLY	25.5	4.7	I9	21	II.8	5.6	48	20
MIDDLE	29.1	4.4	I5	19	10.7	6.0	56	22
LATE	28.8	7.3	25	25	8.7	6.6	75	24
sample site = McNary Dam								
EARLY	30.1	6.6	22	I2	6.8	7.3	107	I2
MIDDLE	30.2	8.0	26	12	6.6	4.1	62	12
LATE	27.6	9.6	35	22	6.7	6.1	90	21

Appendix 9a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Sawtooth SFH branded RD-T-1 sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	52.9	50.2	95	14	107.4	26.2	24	8
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	76.1	16.5	22	12	92.6	18.4	20	8
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	140.1	6.4	5	14	131.8	3.8	3	8
TRUCK	(released at hatchery)							

Appendix 9b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of spring chinook salmon from Sawtooth SFH branded RD-T-1 and sampled for gill NA+-K+ ATPase activity (umoles P_i • mg prot^{-1}•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery on March 15, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	CV	N
sample site = hatchery								
1	ND[1]	ND	ND	ND	5.5	7.0	127	17
2	6.8	1.3	19	20	12.1	6.5	54	19
3	7.6	2.5	33	20	5.4	3.5	65	19
sample site = McNary Dam								
EARLY	MD	ND	ND	ND	ND	ND	ND	ND
MIDDLE	35.0	6.7	19	11	6.4	4.3	67	10
LATE	43.0	12.6	29	19	6.1	5.5	89	18

[1] ND = No data

Appendix 10a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Wells SFH branded LA-7U-1 and Ra-7U-3 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were samples in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

Brand LA-7U-1

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	66.9	26.9	40	19	180.6	43.8	24	20
TRUCK	(Not sampled)							
GLIJCOSE								
HATCHERY	162.3	60.0	37	19	159.2	35.5	22	19
TRUCK	(Not sampled)							
CHLORIDE								
HATCHERY	131.4	9.8	8	19	124.2	8.6	7	20
TRUCK	(Not sampled)							

Brand RA-7U-3

CORTISOL								
HATCHERY	50.8	38.4	76	20	197.3	50.9	26	20
TRUCK	133.6	50.2	38	19	232.0	44.6	19	20
GLUCOSE								
HATCHERY	158.3	50.7	51	20	202.8	71.0	35	18
TRUCK	172.8	93.4	54	19	195.3	65.1	33	20
CHLORIDE								
HATCHERY	129.0	13.2	10	20	118.4	11.9	10	20
TRUCK	130.4	13.1	10	19	124.6	10.6	8	20

Appendix 10b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Wells SFH branded LA-7U-1 and RA-7U-3 and sampled for gill NA^+-K^+ ATPase activity (umoles P_i •mg prot^{-1}•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3 respectively) and again at the early, middle, and late portions of the migrations past Rock Island and McNary dams, spring 1988. Fish were released from the hatchery on April 20, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	CV	N	X	SD	CV	N
Brand LA-7U-1 - Similk.								
sample site = hatchery								
1	10.4	2.0	19	20	11.9	4.4	37	20
2	17.4	2.8	16	20	16.2	6.7	41	19
3	11.4	3.0	26	20	2.5	1.1	44	20
sample site = Rock Island Dam								
EARLY	30.0	9.6	32	21	5.7	6.2	109	20
MIDDLE	ND	ND	ND	ND	ND	ND	ND	ND
LATE	30.9	7.8	25	20	4.8	5.1	106	21
sample site = McNary Dam								
EARLY	35.7	6.4	18	20	5.3	3.6	68	21
MIDDLE	35.4	13.2	37	20	4.3	3.2	75	18
LATE	39.0	8.9	23	20	5.1	5.1	99	21
Brand RA-7U-3								
sample site = hatchery								
1	10.4	2.0	19	20	11.9	4.3	36	20
2	17.4	2.8	16	20	16.2	6.5	40	19
3	11.4	3.0	26	20	2.5	1.1	44	20
sample site = Rock Island Dam								
EARLY	ND	ND	ND	ND	ND	ND	ND	ND
MIDDLE	21.7	6.1	28	17	7.0	5.1	73	17
LATE	23.9	8.8	37	21	8.3	7.6	91	18
sample site = McNary Dam								
EARLY	30.8	6.1	20	19	8.4	9.6	115	19
MIDDLE	32.4	5.6	17	19	5.2	4.5	86	19
LATE	35.8	9.6	27	18	6.5	8.1	125	19

Appendix Ila. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Dworshak NFH branded RA-T-4 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	CV	N
CORTISOL								
HATCHERY	56.4	38.0	68	20	226.4	59.1	26	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	124.0	55.3	45	20	132.7	35.5	27	19
TRUCK	(released at hatchery)							
CHLORIDE								
HATCHERY	134.0	6.5	5	19	130.3	6.0	5	19
TRUCK	(released at hatchery)							

Appendix llb. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Dworshak NFH branded RA-T-4 and sampled for gill NA^{+}-K^{+} ATPase activity (umoles Pi'mg $prot^{-1}$. hr^{-1}), and thyroxine ($ng \cdot mL^{-1}$). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2, 3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite dam, spring 1988. Fish were released from the hatchery on May 2, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	CV	N	X	SD	cv	N
sample site = hatchery								
1	7.8	1.8	24	19	8.5	4.6	54	19
2	9.9	3.0	30	19	13.0	7.2	55	18
3	10.9	2.4	22	20	14.9	10.9	73	20
sample site = Lower Granite Dam								
EARLY	16.5	4.4	27	18	12.2	9.1	75	19
MIDDLE	21.6	7.5	35	20	13.7	12.1	88	20
LATE	23.1	5.5	24	23	13.3	6.6	50	22

Appendix 12a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Hagerman NFH branded LD-T-2 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	14.6	10.8	73	20	135.1	41.3	31	19
TRUCK	136.0	56.9	42	20	253.2	53.0	21	20
GLUCOSE								
HATCHERY	116.2	30.4	26	20	131.0	30.9	24	19
TRUCK	109.3	18.7	17	19	114.6	28.4	25	18
CHLORIDE								
HATCHERY	142.0	3.6	2	20	136.4	4.5	3	19
TRUCK	132.6	7.2	5	20	130.6	4.0	3	20

Appendix 12b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Hagerman NFH branded LD-T-2 and sampled for gill $NA^{+}-K^{+}$ ATPase activity (umoles $P_i \cdot mg\ prot^{-1} \cdot hr^{-1}$) and thyroxine ($ng \cdot mL^{-1}$). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite dam, spring 1988. Fish were released on April 17, 1988.

SAMPLE TIME	$Na^{+}-K^{+}$ ATPase X	SD	CV	N	Thyroxine X	SD	cv	N
sample site = hatchery								
1	7.3	2.0	27	17	6.0	4.1	70	13
2	6.6	2.3	35	20	7.2	5.8	80	20
3	7.0	1.0	14	20	4.1	1.6	40	20
sample site = Lower Granite Dam								
EARLY	29.7	8.9	30	21	22.5	11.0	49	21
MIDDLE	31.4	6.1	20	20	12.4	5.1	41	19
LATE	ND[1]	ND	ND	ND	ND	ND	ND	ND

[1] ND = No data

Appendix 13a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV) and sample size (N) of steelhead from Irrigon SFH branded RA-IF/IM-1 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

	RESTING				STRESSED			
SAMPLE	X	SD	CV	N	X	SD	cv	N
CORTISOL								
HATCHERY	31.6	18.2	58	20	188.5	40.1	21	20
TRUCK	176.6	65.2	37	19	251.9	66.3	26	19
GLUCOSE								
HATCHERY	114.2	19.8	17	19	163.9	40.8	25	18
TRUCK	137.3	29.2	21	17	144.7	27.1	19	11
CHLORIDE								
HATCHERY	133.8	3.7	3	19	133.9	4.0	3	18
TRUCK	123.4	5.8	5	18	121.6	6.0	5	18

Appendix 13b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Irrigon SFH branded RA-IF/IM-1 and sampled for gill NA^+-K^+ ATPase activity (umoles P_i•mg $prot^{-1}$•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite and McNary dams, spring 1988. Fish were released between April 21 and April 24, 1988.

	Na^+-K^+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	8.0	2.1	26	19	4.8	3.5	74	20
2	11.2	3.8	34	20	7.1	3.6	50	18
3	11.8	3.4	29	20	4.8	1.8	38	20
sample site = Lower Granite Dam								
EARLY	20.8	5.2	25	33	19.1	12.2	64	29
MIDDLE	27.3	8.2	30	20	16.9	8.8	52	14
LATE	27.5	5.9	21	29	14.1	11.7	83	24
sample site = McNary Dam								
EARLY	27.0	13.4	49	8	10.1	6.3	62	9
MIDDLE	30.7	8.1	26	11	7.9	7.4	94	13
LATE	31.6	8.2	26	15	10.7	11.7	109	15

Appendix 14a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Lyons Ferry SFH branded LA/RA-S-1/2 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED) prior to release from the hatchery.

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	10.6	8.8	83	18	123.1	49.6	40	20
TRUCK	(released at hatchery)							
GLUCOSE								
HATCHERY	113.2	18.4	16	20	143.1	25.1	18	18
TRUCK	(released at hatchery)							
CHLOHIDE								
HATCHERY	126.6	4.4	4	20	117.3	3.8	3	19
TRUCK	(released at hatchery)							

Appendix 14b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Lyons Ferry SFH branded LA/RA-S-1/2 and sampled for gill NA^{+}-K^{+} ATPase activity (umoles P_i•mg $prot^{-1}$•hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 7 weeks, 5 weeks, 3 weeks, and immediately prior to release (1,2,3,4 respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery on April 29, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	8.7	3.3	38	20	6.4	2.8	44	19
2	12.1	4.9	40	20	15.8	9.5	60	18
3	13.0	5.9	45	19	8.8	5.1	58	19
4	11.7	5.7	49	20	6.7	5.2	78	20
sample site = McNary Dam								
EARLY	26.2	7.1	27	22	16.6	10.4	62	21
MIDDLE	27.7	8.4	30	19	9.3	5.6	60	20
LATE	27.4	10.8	39	20	12.4	9.6	77	20

Appendix 15a. Summary of mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Niagara Springs SFH branded LD-T-3 and sampled for plasma cortisol ($ng \cdot mL^{-1}$), glucose ($mg \cdot dL^{-1}$), and chloride ($meq \cdot L^{-1}$) during spring 1988. Samples were taken prior to loading on the transport truck (HATCHERY) and during release from the truck (TRUCK). Fish were sampled in a resting state (RESTING) and one hour after a stress challenge (STRESSED).

	RESTING				STRESSED			
SAMPLE	X	SD	cv	N	X	SD	cv	N
CORTISOL								
HATCHERY	33.0	19.7	60	20	145.3	84.7	58	20
TRUCK	194.8	57.0	29	20	261.7	50.0	19	20
GLUCOSE								
HATCHERY	96.3	24.3	25	20	109.7	21.0	19	18
TRUCK	116.6	14.7	13	19	129.5	23.8	18	18
CHLORIDE								
HATCHERY	142.3	4.7	3	20	137.3	9.3	7	19
TRUCK	126.0	3.9	3	19	117.2	8.2	7	20

Appendix 15b. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of steelhead from Niagara Springs SFH branded LD-T-3 and sampled for gill NA^+-K^+ ATPase activity (umoles P_i •mg $prot^{-1}$: hr^{-1}) and thyroxine (ng•mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past Lower Granite dam, spring 1988. Fish were released from the hatchery on April 23, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	6.5	1.4	21	20	4.5	2.4	53	20
2	6.3	1.7	27	19	4.8	3.2	65	20
3	6.9	1.8	26	20	5.8	3.0	51	20
sample site = Lower Granite Dam								
EARLY	29.5	6.7	23	19	24.3	11.3	46	20
MIDDLE	34.1	9.7	28	20	17.0	9.1	54	19
LATE	35.8	10.1	28	24	14.9	10.0	67	23

Appendix 16. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of subyearling fall chinook salmon from Priest Rapids SFH branded LA/RA-R-1/2 and-sampled for gill NA^+-K^+ ATPase activity (umoles Pi·mg prot^{-1} • hr) and thyroxine (ng . mL^{-1}). Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery between June 6 and June 18, 1988.

	Na^+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	CV	N
sample site = hatchery								
1	9.1	4.3	47	10	4.2	1.9	46	8
2	17.8	5.8	32	20	5.3	3.4	64	18
3	14.8	4.5	30	20	6.9	4.0	58	20
sample site = McNary Dam								
EARLY	27.4	3.8	14	20	6.0	9.1	152	19
MIDDLE	32.3	5.8	18	20	3.0	1.4	49	20
LATE	39.7	6.2	16	42	3.3	1.4	44	42

Appendix 17. Mean (X), standard deviation (SD), coefficient of variation (CV), and sample size (N) of subyearling fall chinook salmon from Lyons Ferry SFH branded RA-R-1 and sampled for gill NA^+-K^+ ATPase activity (umoles $P_i \cdot mg\ prot^{-1} \cdot hr^{-1}$) and thyroxine ($ng \cdot mL^{-1}$) Samples were taken from the hatchery 4 weeks, 2 weeks, and immediately prior to release (1,2,3, respectively) and again at the early, middle, and late portions of the migrations past McNary dam, spring 1988. Fish were released from the hatchery on June 1, 1988.

	Na+-K+ ATPase				Thyroxine			
SAMPLE TIME	X	SD	cv	N	X	SD	cv	N
sample site = hatchery								
1	10.9	3.5	32	15	3.5	1.3	36	5
2	11.7	6.5	55	15	4.7	3.4	72	12
3	23.8	7.7	32	15	4.9	3.6	73	14
sample site = McNary Dam								
EARLY	ND[1]	ND	ND	ND	ND	ND	ND	ND
MIDDLE	40.7	6.6	16	10	3.3	1.4	41	10
LATE	34.4	3.2	9	11	4.0	2.4	62	11

[1] ND = No data

Appendix 18. Summary of mean (X) guanine (Gn) and hypoxanthine (Hx) (mg/g tissue), mean fork length (mm), mean gill Na^+-K^+ ATPase activity (umoles Pi 'mg protein^{-1}•h^{-1}), standard deviation (SD), coefficient of variation (CV in percent), and sample size (N) of juvenile spring chinook originating from Winthrop NFH, sampled at McNary Dam during May and June, 1988.

Date	5-17-88 N = 16	5-24-88 N = 11	6-2-88 N= 12	6-7-88 N = 3
[Guanine]				
X	39.74	40.60	44.52	55.00
SD	12.21	9.23	11.38	11.89
cv	31	23	26	22
[Hypoxanthine 1				
X	10.50	10.49	10.51	10.64
SD	4.01	2.66	1.99	1.36
cv	38	25	19	13
[Gn+Hx]				
X	50.23	51.09	55.03	65.64
SD	15.78	10.84	12.85	12.98
cv	31	21	23	20
[Gn]/[Hx]				
X	3.94	3.96	4.26	5.16
S D	0.79	0.90	0.81	0.73
cv	20	23	19	14
Fork Length				
X	154	152	157	159
SD	14	7	14	6
cv	9	5	9	4
ATPase				
N	20	20	20	NA
X	33.1	35.0	39 .o	NA
SD	7.4	5.5	6.8	NA
cv	22	16	17	NA

Appendix 19. Summary of organosomatic examinations of chinook salmon from Entiat NFH conducted at the hatchery and as the migration passed Rock Island and McNary dams during the spring of 1988. Unlisted categories were rated as normal. ND = data not available.

	HATCHERY	ROCK ISLAND DAM	MCNARY DAM
N	60	15	34
Kfl	1.03	.96	ND
Plasma Protein ($g \cdot dL^{-1}$)	3.6	2.6	ND
Mesenteric Fat (%)			
0	40	80	100
1	47	20	0
2	13	0	0
3	0	0	0
Mean value	0.7	0.2	0.0
Thymus (%)			
0	72	87	71
1	28	13	20
2	0	0	9
Bile (%)			
0	57	13	21
1	33	20	49
2	8	47	27
3	2	20	3

Comments: 6% enlarged spleen
3% with nodules in spleen

Appendix 20. Summary of organosomatic examinations of chinook salmon from Leavenworth NFH conducted at the hatchery and as the migration passed Rock Island and McNary dams during the spring of 1988. Unlisted categories were rated as normal. ND = data not available.

	HATCHERY	ROCK ISLAND DAM	MCNARY DAM
N	60	49	24
Kfl	1.02	.96	ND
Plasma Protein ($g \cdot dL^{-1}$)	4.2	3.6	ND
Mesenteric Fat (%)			
0	5	20	88
1	57	45	12
2	36	31	0
3	2	4	0
Mean Value	1.4	1.2	0.1
Thymus (%)			
0	45	90	75
1	52	10	17
2	3	0	8
Bile (%)			
0	50	27	37
1	50	41	42
2	0	22	21
3	0	10	0
Comments:		2% granular spleen 16% fatty liver 2% general liver discoloration	20% enlarged spleen 12% fatty liver 4% nodules in liver 12% mottled kidney

Appendix 21. Summary of organosomatic examinations of chinook salmon from Winthrop NFH conducted at the hatchery and as the migration passed Rock Island and McNary dams during the spring of 1988. Unlisted categories were rated as normal, ND = data not available.

	HATCHERY	ROCK ISLAND DAM	MCNARY DAM
N	60	72	20
Kfl	1.09	.94	ND
Plasma Protein ($g \cdot dL^{-1}$)	5.3	3.7	ND
Mesenteric Fat (%)			
0	6	28	75
1	54	46	25
2	30	22	0
3	10	4	0
Mean value	1.4	1.0	0.2
Thymus (%)			
0	64	82	65
1	31	18	30
2	5	0	5
Bile (%)			
0	25	11	6
1	66	18	22
2	5	38	56
3	4	33	16
Comments:	5% enlarged spleen	7% enlarged spleen	10% fatty liver 10% discolored liver 15% granular kidney 5% mottled kidney 40% enlarged spleen

Appendix 22. Summary of organosomatic examinations of chinook salmon from Dworshak NFH conducted at the hatchery and as the migration passed McNary dam during the spring of 1988. Unlisted categories were rated as normal. ND = data not available.

	HATCHERY	MCNARY DAM
N	100	8
K_{fl}	1.06	ND
Plasma ($g \cdot dL^{-1}$) Protein	6.2	ND
Mesenteric Fat (%)		
0	0	100
1	25	0
2	68	0
3	7	0
Mean value	1.8	0.0
Thymus (%)		
0	94	50
1	5	50
2	1	0
Bile (%)		
0	NA	50
1	NA	0
2	NA	50
3	NA	0

Comments:

4% granular spleen
4% discoloration of liver
3% inflamed or swollen pseudobranchs
12% focal discoloration of liver

Appendix 23. Summary of organosomatic examinations of steelhead trout from Hagerman NFH and Niagara Springs SFH conducted at the hatcheries during the spring of 1988. Unlisted categories were rated as normal.

	HAGERMAN NFH	NIAGARA SPRINGS SFH
N	59	60
K_{fl}	1.03	1.03
Plasma Protein ($g \cdot dL^{-1}$)	4.5	3.9
Mesenteric Fat (%)		
0	0	0
1	10	18
2	34	42
3	56	40
Mean value	2.5	2.2
Thymus (%)		
0	76	90
1	24	10
2	0	0
Bile (%)		
0	3	18
1	70	70
2	12	12
3	15	0

Comments:

5% mild inflammation of hindgut
3% enlarged spleen
2% granular spleen
2% frayed gills

2% enlarged spleen
18% granular spleen

Appendix 24. Summary of organosomatic examinations of steelhead trout from Irrigon SFH conducted at the hatchery and as the migration passed McNary dam during the spring of 1988. Unlisted categories were rated as normal. ND = data not available.

	HATCHERY	MCNARY DAM
N	60	21
K_{fl}	1.10	ND
Plasma Protein ($g \cdot dL^{-1}$)	5.2	ND
Mesenteric Fat (%)		
0	0	76
1	2	19
2	58	5
3	40	0
Mean value	2.4	0.3
Thymus (%)		
0	83	100
1	17	0
2	0	0
Bile (%)		
0	73	32
1	25	5
2	2	63
3	0	0

Comments:

5% severe inflammation of hindgut
5% nodules in liver
5% mottled liver
5% hemorrhage in one eye