An Assessment of the Relationship Between Smolt Development and Fish Guidance Efficiency at Bonneville Dam

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COASTAL ZONE AND ESTUARINE STUDIES

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2725 Montlake Boulevard East
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CONTENTS

INTRODUCTION

Research conducted by the National Marine Fisheries Service (NMFS) in cooperation with the U.S. Army Corps of Engineers (COE) has demonstrated that fish guidance efficiency (FGE) not only changes from year to year and among dams, but can also change during the course of any year's outmigration and even within a day. Of juvenile salmonids entering a turbine intake, FGE is the proportion that are guided into the gatewells and accompanying bypass system. Data acquired at Lower Granite and Little Goose Dams from 1985 to 1987 suggest that intraseasonal changes in FGE are associated with the changing physiological status of the smolt population. NMFS researchers have presented evidence which indicates that yearling chinook salmon, Oncorhynchus tshawytscha, that are fully smolted within the population are more susceptible to guidance by traveling screens (Giorgi et al. 1988; Muir et al. 1988). We hypothesize that over the course of the outmigration the proportion of fully smolted fish in the population increases, which in turn explains intraseasonal increases in FGE observed at Lower Granite Dam.

Since 1983, NMFS has been conducting research at Bonneville Dam to evaluate and improve FGE at the Second Powerhouse. Results have often been disappointing despite many structural modifications to the collection system (Gessel et al. 1988). One factor that may be influencing these results is the extent to which the physiological status of the smolt population changes during the outmigration. The purpose of this study is to determine if seasonal changes in the physiological status of the migrant population are evident at Bonneville Dam, and assess whether those changes are related to concurrent FGE estimates.

METHODS AND MATERIALS

Gill Na^+-K^+ ATPase

To examine the relationship between fish guidability and smolt development, juvenile salmonids were collected during FGE tests and assayed for gill Na^+-K^+ ATPase. Chinook salmon and coho salmon, O. kisutch, (20 each) were sampled from the gatewell and each net level (excluding the gap net) in the center column and placed on ice until gill samples could be taken. The fyke net array was the standard configuration used in FGE evaluation (Fig. 1). Fish were weighed and measured; gill filaments were trimmed from the gill arch and placed into 1.5-ml microcentrifuge tubes filled with a buffer solution containing sucrose, ethylenediamine, and imidazole. Samples were immediately placed in a freezer and held at <-20°C until assayed.

To assure that any observed differences in gill Na^+-K^+ ATPase between live gatewell captured and dead fyke-net captured fish were not caused by deterioration of this enzyme in the dead fish, gatewell fish were killed and placed in water at ambient river temperature until the fyke nets were removed from the water. The net catches were then processed in a random order so that the time elapsed between death and gill removal did not consistently favor any net level or the gatewell. Assays for gill Na^+-K^+ ATPase were conducted using procedures described by Zaugg (1982) with minor modification.

To test for differences in gill Na^+-K^+ ATPase between guided and unguided fish, data from fish sampled from the fyke nets were combined and compared to those fish sampled from the gatewell using the Mann-Whitney U-statistic (Sokal and Rohlf 1981). To characterize the physiological status of the smolt population on each sample date, the mean gill Na^+-K^+ ATPase level was determined for each net level, weighted for the number of fish captured at that level, and averaged. Correlations between smoltification and fish guidance estimators including FGE, theoretical fish guidance

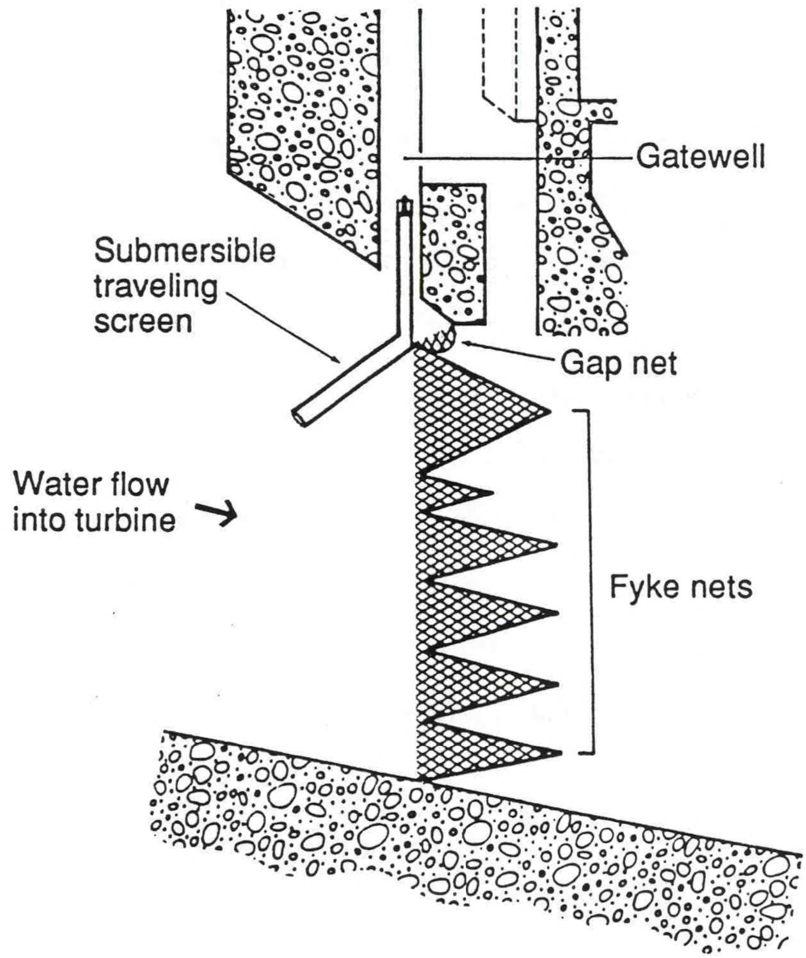

Figure 1.--Cross section of turbine intake at Lower Granite Dam. Fyke-net frame used for fish guidance efficiency sampling is situated behind and below the submersible traveling screen and projects downward to the floor of the intake.

efficiency (TFGE), and guidance device efficiency were then examined. TFGE is the proportion of fish entering the turbine intake which should be intercepted and guided; it is estimated by suspending a fyke-net array in an intake without an STS in place. Guidance device efficiency is determined by dividing FGE by TFGE.

Condition Factor

We assessed the feasibility of using condition factor as an index of smolt development in FGE studies. Our concern was that fyke-net caught fish could be dead for up to 3 h before processing. During that time they may absorb water which increases their weight and alters condition factor. If such a condition existed, a comparison of condition factors derived from fyke-net caught and fresh-killed gatewell fish may not be valid. To assess this potential problem, samples of 20 fresh-killed yearling chinook and coho salmon were periodically fin clipped, measured, weighed, and placed in a fyke net prior to deploying the net for an FGE test. Following the FGE test the marked fish were removed from the net and reweighed and measured. Condition factors were calculated for both sets of samples and compared using a Mann-Whitney statistic. In addition, two samples of subyearling chinook salmon captured in the gatewell were weighed and measured immediately after capture, killed, held in water on deck, and reweighed and measured 3 h later and condition factors similarly compared.

Sampling Protocol

At the Second Powerhouse during the spring outmigration, we acquired samples from FGE tests on six dates for yearling chinook salmon and five dates for coho salmon (Table 1). At the First Powerhouse, only one sample for coho salmon was obtained since few of these species were passing the facility during the test period (Table 2). For the same reason, no sockeye salmon, *O. nerka*, subyearling chinook salmon, or steelhead, *O. mykiss* (formerly *Salmo gairdneri*), were sampled during the spring at either powerhouse.

Table 1.--Fish guidance efficiency (FGE), number of coho, subyearling chinook, and yearling chinook salmon captured in the gatewell and fyke nets (n), and test conditions at Bonneville Dam, Second Powerhouse (PH) during smoltification studies, 1988. FGE test conditions on any date are detailed in Gessel et al. (1988).

Date	PH/unit	Species	n	FGE (%)
2 May	2/12B	Yr. chin.	406	32.3
3 May	2/12B	Yr. chin.	463	31.7
9 May	2/12B	Yr. chin.	184	53.3
10 May	2/12B	Yr. chin.	172	43.0
15 May	2/12B	Yr. chin.	178	52.8
16 May	2/12B	Yr. chin.	334	57.5
15 May	2/12B	Coho	219	75.3
16 May	2/12B	Coho	449	68.8
26 May	2/12B	Coho	210	68.1
31 May	2/12B	Coho	316	58.9
1 June	2/12B	Coho	110	50.0
6 July	2/12B	Sub. chin.	941	49.4
7 July	2/12B	Sub. chin.	543	46.8
18 July	2/12B	Sub. chin.	656	24.5
19 July	2/12B	Sub. chin.	335	35.8
25 July	2/12B	Sub. chin.	415	27.5
26 July	2/12B	Sub. chin.	384	50.3

Table 2.-- Fish guidance efficiency, number of coho and subyearling chinook salmon captured in the gatewell and fyke nets (n), and test conditions at Bonneville Dam, First Powerhouse (PH) during smoltification studies, 1988.

Date	PH/unit	Test conditions	Species	n	FGE (%)
1 June	1/3B	Standard STS	Coho	359	56.8
6 July	1/3B	Standard STS	Sub. chin.	1,225	9.8
8 July	1/3B	Standard STS	Sub. chin.	724	11.6
18 July	1/3B	Standard STS	Sub. chin.	569	8.1
19 July	1/3B	Standard STS	Sub. chin.	485	17.3
25 July	1/3B	Standard STS	Sub. chin.	1,473	13.6
26 July	1/3B	Standard STS	Sub. chin.	797	5.9

During July, samples of subyearling chinook salmon were collected on six dates at each powerhouse (Tables 1 and 2). Two additional sets of samples for yearling chinook salmon were collected from vertical distribution tests conducted at the Second Powerhouse on 26 April and 17 May.

RESULTS

FGE and Smoltification

Yearling chinook salmon exhibited a steady increase in gill Na^+-K^+ ATPase activity during the spring sampling period (Fig. 2). Weighted mean values for the enzyme increased from a low of 22.6 on 26 April to a high of 32.1 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$ on 16 May 1988 (Table 3). By comparison, Na^+ -K^+ ATPase levels in coho salmon were constant and lower (Fig. 2). Between 15 May and 1 June the enzyme activity fluctuated only 3.5 units, ranging from 20.2 to 23.7 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$. At both powerhouses subyearling chinook salmon exhibited a general decrease in enzyme activity over the 20-d summer sampling period (Fig. 3). Mean enzyme levels ranged from 31.5 to 40.4 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$ and 29.9 to 40.8 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$. at the First and Second Powerhouses, respectively (Tables 3 and 4). Detailed results are contained in Appendix Tables 1-5.

Correlations between smolt development and FGE estimates were examined using the weighted mean enzyme level versus the FGE, guidance device efficiency, and TFGE estimator on each sampling date. No correlations between smolt development and any of the fish guidance estimators were apparent (Table 5).

When gill Na^+ -K^+ ATPase levels of guided and unguided fish were compared, no consistent patterns were identified. For yearling chinook salmon collected at the Second Powerhouse, guided fish had significantly higher enzyme levels than unguided fish on two of six sample dates (Table 6 and Fig. 4). However, on 15 May, unguided yearling chinook salmon had significantly higher Na^+-K^+ ATPase levels than those that

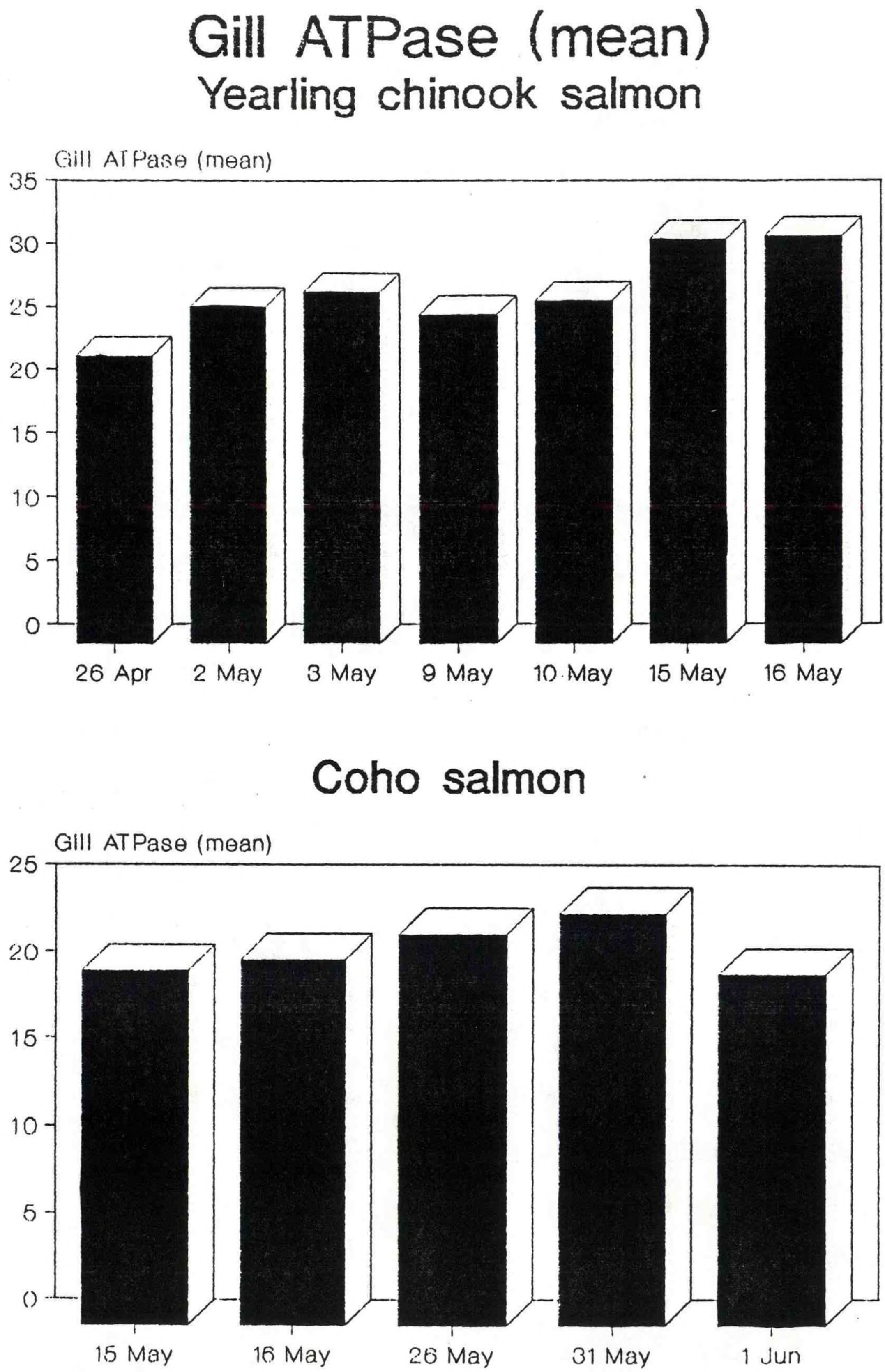

Figure 2.--Weighted mean gill Na^{+}-K^{+} ATPase (µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) from yearling chinook and coho salmon collected at Bonneville Dam, Second Powerhouse, 1988.

Table 3.--Fish guidance (FGE), theoretical fish guidance efficiency (TFGE), guidance device efficiency (GDE), and corresponding gill Na^{+}-K^{+} ATPase (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) activity level (weighted mean) from Bonneville Dam, Second Powerhouse, 1988.

Date	Species	FGE (%)	TFGE (%)	GDE (%)	ATPase (mean)
26 Apr	Yr. chinook	*	*	*	22.6
2 May	Yr. chinook	32.3	63.5	50.9	26.4
3 May	Yr. chinook	31.7	66.9	47.4	27.6
9 May	Yr. chinook	53.3	66.7	79.9	25.8
10 May	Yr. chinook	43.0	59.1	72.8	26.9
15 May	Yr. chinook	52.8	52.5	100.6	31.8
16 May	Yr. chinook	57.5	74.7	76.9	32.1
17 May	Yr. chinook	*	44.4	*	32.1
15 May	Coho	75.3	67.0	112.4	20.4
16 May	Coho	68.8	75.2	91.5	21.0
26 May	Coho	68.1	78.6	86.6	22.5
31 May	Coho	58.9	71.0	83.0	23.7
1 Jun	Coho	50.0	61.7	81.0	20.2
6 Jul	Sub. chinook	49.4	65.5	75.5	39.4
7 Jul	Sub. chinook	46.8	70.2	66.7	40.8
18 Jul	Sub. chinook	24.5	43.9	55.9	36.7
19 Jul	Sub. chinook	35.8	49.7	72.1	29.9
25 Jul	Sub. chinook	27.5	43.6	62.9	30.8
26 Jul	Sub. chinook	50.3	40.3	124.8	31.8

* Gill samples collected from vertical distribution tests.

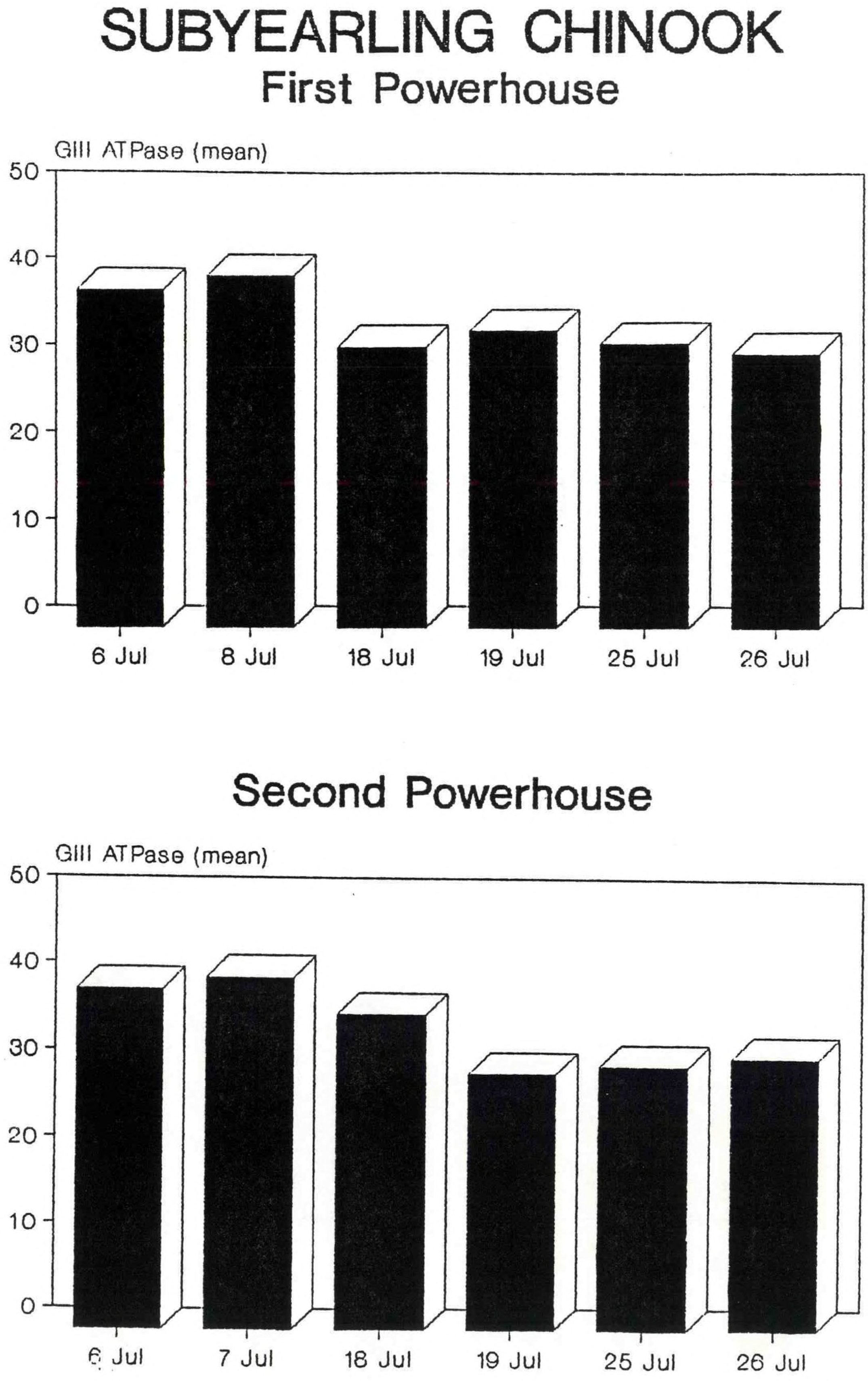

Figure 3.--Weighted mean gill Na^{+}-K^{+} ATPase (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) from subyearling chinook salmon collected at Bonneville Dam, 1988.

Table 4.--Fish guidance efficiency (FGE) and corresponding gill Na^{+}-K^{+} ATPase (µmol P_i . mg $Prot^{-1} \cdot h^{-1}$) activity level (weighted mean) from Bonneville Dam, First Powerhouse, 1988.

Date	Species	FGE (%)	ATPase (mean)
1 Jun	Coho	56.8	21.3
6 Jul	Sub. chinook	9.8	38.8
8 Jul	Sub. chinook	11.6	40.4
18 Jul	Sub. chinook	8.1	32.2
19 Jul	Sub. chinook	17.3	34.1
25 Jul	Sub. chinook	13.6	32.7
26 Jul	Sub. chinook	5.9	31.5

Table 5.--Product-moment correlation coefficients (r) between weighted mean gill Na^{+}-K^{+} ATPase levels and various fish guidance efficiency estimators at Bonneville Dam, Second Powerhouse, 1988.

Species	FGE	TFGE	Guidance device efficiency
Yearling chinook	0.5772	-0.0045	0.5646
Subyearling chin.	0.3553	0.8000	-0.2958
Coho	-0.0646	0.5534	-0.4318

Table 6.--Results of Mann-Whitney tests for guided vs unguided fish Na^{+}-K^{+} ATPase activity (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) at Bonneville Dam, Second Powerhouse, 1988.

Date	Species	Na^{+}-K^{+} ATPase (mean) Gatewell	Nets	P
2 May	Yr. chinook	29.8	24.8	0.0290*
3 May	Yr. chinook	31.1	25.6	0.0063**
9 May	Yr. chinook	24.8	26.8	0.3484
10 May	Yr. chinook	27.8	25.7	0.3224
15 May	Yr. chinook	29.7	35.1	0.0304*
16 May	Yr. chinook	32.9	30.5	0.1489
15 May	Coho	19.3	24.6	0.0577
16 May	Coho	19.4	24.7	0.0374*
26 May	Coho	23.7	18.6	0.0012**
31 May	Coho	25.3	20.9	0.0050**
1 Jun	Coho	18.3	22.6	0.0021**
6 Jul	Sub. chinook	39.9	38.7	0.4914
7 Jul	Sub. chinook	40.0	41.9	0.5527
18 Jul	Sub. chinook	30.6	38.0	0.0007***
19 Jul	Sub. chinook	32.0	27.8	0.0296*
25 Jul	Sub. chinook	28.0	32.2	0.0194*
26 Jul	Sub. chinook	33.1	30.4	0.1401

* $0.01 < P < 0.05$
** $0.001 < P < 0.01$

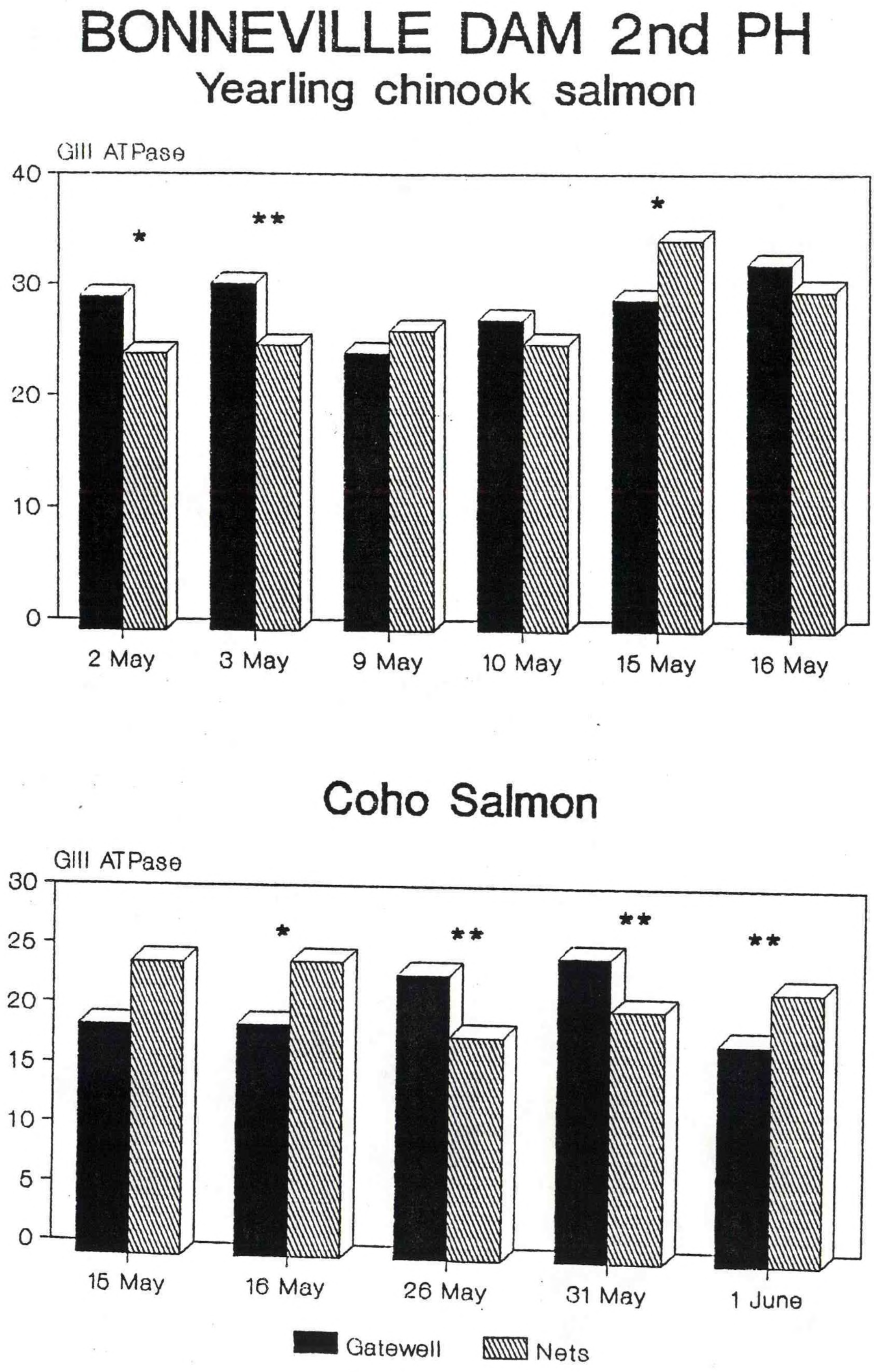

Figure 4.--A comparison of gill Na^{+}-K^{+} ATPase levels (µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) in yearling chinook and coho salmon measured in gatewell caught (guided) vs those captured in the fyke nets (unguided) at Bonneville Dam, Second Powerhouse, 1988. Indicated levels of significance are results of Mann-Whitney U tests: * , $0.01 < P < 0.05$; ** , $0.001 < P < 0.01$; *** , $P < 0.001$.

were guided. On the remaining three dates no differences in enzyme activity were evident.

For coho salmon captured at the Second Powerhouse, Na^{+}-K^{+} ATPase levels in guided fish were significantly higher on two and significantly lower on two of five dates (Table 6 and Fig. 4). For the one sample of coho salmon from the First Powerhouse, no difference in enzyme levels of guided and unguided fish was evident (Table 7).

Guided subyearling chinook salmon sampled at the Second Powerhouse had significantly higher Na^{+}-K^{+} ATPase levels than unguided fish on one of six test dates and significantly lower levels on two dates (Table 6 and Fig. 5). Results obtained from the First Powerhouse were similar, with guided subyearling chinook salmon having significantly higher levels on two dates and significantly lower levels on one date (Table 7 and Fig. 5).

There was no significant difference in the physiological status of subyearling chinook salmon captured at the two powerhouses during the summer ($t = 0.04$, d.f. = 5, $P = 0.9680$).

Condition Factor

All species examined exhibited significant changes in condition factors from life until they were remeasured and reweighed 3 h after death (Table 8). For both yearling chinook and coho salmon, the condition factor increased following death. This was due to an apparent decrease in fork length (an average of 1.9 to 3.1 mm) and concomitant increase in weight (Table 8). The apparent decrease in length was caused by caudal fin fraying and splitting while in the fyke nets, resulting in our inability to accurately identify the edge of the caudal fin. One sample of subyearling chinook salmon exhibited a significant decrease in condition factor, while a second sample showed no change. In contrast to yearling chinook and coho salmon, subyearling chinook salmon displayed an increase in length (0.6 to 1.7 mm) following death (Table 8). However,

Table 7.--Results of Mann-Whitney tests for guided vs unguided fish Na^{+}-K^{+} ATPase activity (μmol P_i · mg $Prot^{-1}$ · h^{-1}) at Bonneville Dam, First Powerhouse, 1988.

Date	Species	Na^{+}-K^{+} ATPase (mean)		P
		Gatewell	Nets	
1 Jun	Coho	21.2	21.0	0.8420
6 Jul	Sub. chinook	45.6	37.9	0.0021**
8 Jul	Sub. chinook	35.9	39.3	0.0586
18 Jul	Sub. chinook	36.6	32.7	0.0337*
19 Jul	Sub. chinook	37.2	33.4	0.0904
25 Jul	Sub. chinook	29.9	32.0	0.2585
26 Jul	Sub. chinook	26.0	32.5	0.0032**

* $0.01 < P < 0.05$
** $0.001 < P < 0.01$

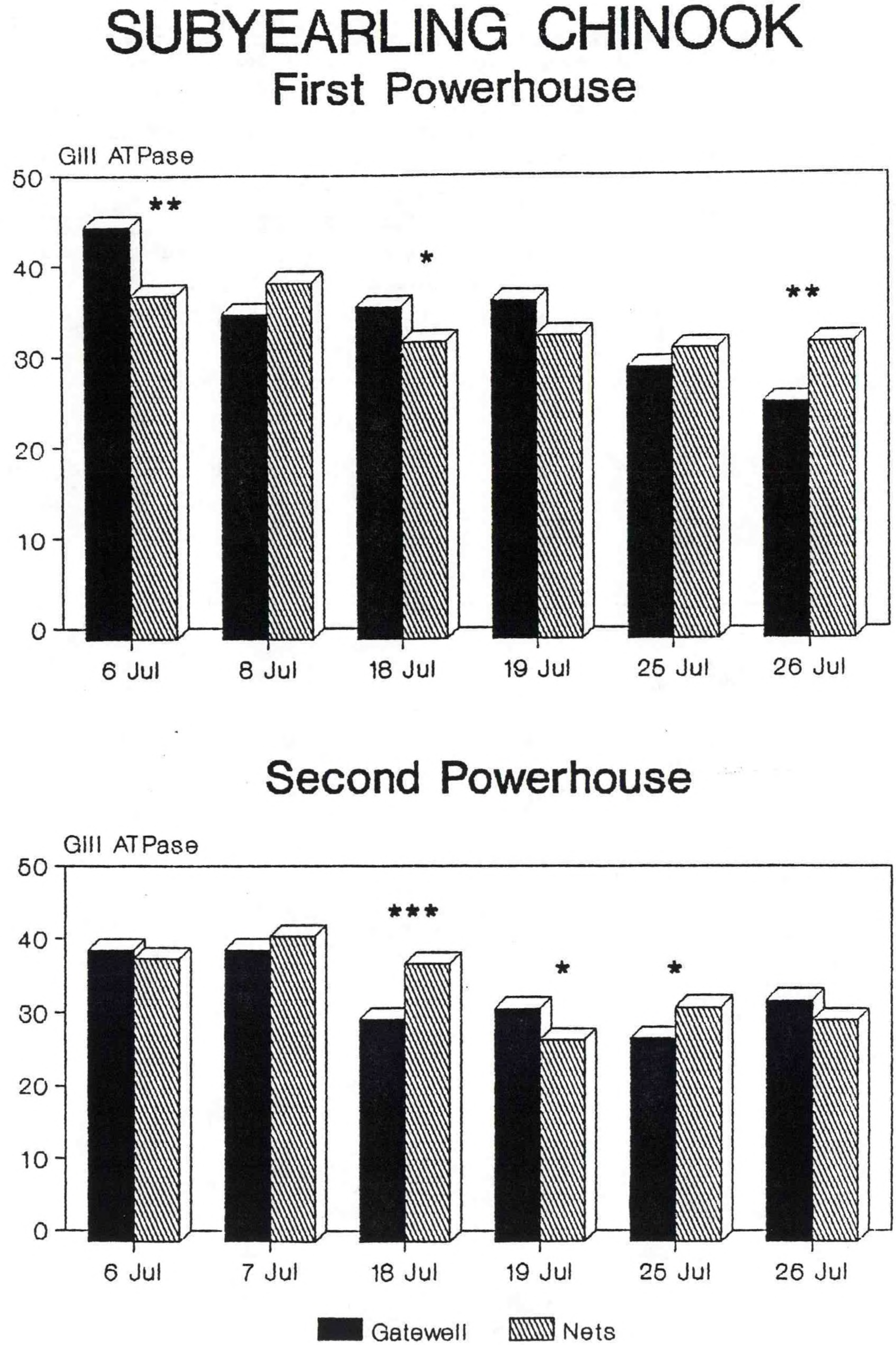

Figure 5.--A comparison of gill Na^+-K^+ ATPase levels (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) in subyearling chinook salmon measured in gatewell caught (guided) vs those captured in the fyke nets (unguided) at Bonneville Dam, 1988. Indicated levels of significance are results of Mann-Whitney U tests: * , $0.01 < P < 0.05$; ** , $0.001 < P < 0.01$; *** , $P < 0.001$.

Table 8.--Changes in length, weight, and condition factor for salmonids measured live and approximately 3 h after death. Yearling chinook and coho salmon were placed in fyke nets during the elapsed time. Subyearling chinook salmon were held in running water on deck during the elapsed time on two separate dates. The Mann-Whitney test was used to determine probability.

Species	n	Change in length (mm)	P	Change in weight (g)	P	Change in condition-factor	P
Yearling chinook	25	- 1.9	0.6415	+ 0.34	0.8159	+ 0.044	0.0446*
Coho	22	- 3.1	0.9532	+ 0.02	0.2649	+ 0.066	0.0004***
Sub. chinook	20	+ 1.7	0.5792	+ 0.26	0.6949	- 0.034	0.0499*
Sub. chinook	20	+ 0.6	0.7150	+ 0.30	0.6158	+ 0.007	0.9138

* $0.01 < P < 0.05$
*** $0.01 < P < 0.001$

this was a consequence of the subyearling chinook salmon being held in a vessel of static water rather than in fyke nets for 2 or 3-h periods. Consequently the caudal fins were not split or frayed, and the edge of the caudal fin was easily identified for measurement.

DISCUSSION

Smoltification data collected at Bonneville Dam during the 1988 field season indicated that physiological status of yearling and subyearling chinook salmon varied over the course of the outmigration. Weighted mean gill Na^+-K^+ ATPase levels for subyearling chinook salmon decreased steadily at both powerhouses over the July sample period while, in general, FGE also decreased. However, changing test conditions and altered flow conditions also affected FGE, confounding our ability to detect a correlation between smoltification status and the FGE estimate, if one exists. The enzyme levels in yearling chinook salmon increased over the spring outmigration (Fig. 2). This is consistent with patterns observed at both Lower Granite and Little Goose Dams (Muir et al. 1988). However, a relationship between smolt development and concurrent estimates of FGE was not apparent for either race of chinook salmon (Table 5). This was in part due to the changing conditions employed during FGE testing (Table 1) which made the relationship between FGE and smoltification status difficult to isolate. For that reason we also examined relationships between gill enzyme levels and two other measures of guidance, guidance effectiveness and TFGE, but no relationships could be demonstrated (Table 5).

At the Second Powerhouse, guided yearling chinook salmon exhibited significantly higher gill Na^+-K^+ ATPase levels on the first two dates sampled (2-3 May) compared with unguided fish. Similar results were obtained in 1986 at Little Goose Dam (Swan et al. 1987) and at Lower Granite Dam in 1987 (Muir et al. 1988) where significant differences were found early in the outmigration when gill Na^+-K^+ ATPase levels were relatively low. However, when gill Na^+-K^+ ATPase levels were higher later in the year, such differences were not apparent. During the 1987 outmigration at Little Goose Dam, gill enzyme levels were always high and no significant differences between guided and unguided yearling chinook salmon were observed (Muir et al. 1988).

A possible explanation for this apparent intraseasonal change in yearling chinook salmon guidance behavior could be that fish in the early or transitional stages of the parr/smolt transformation could be more demersally oriented than fully smolted individuals, resulting in poor guidance. Yearling chinook salmon, advanced in their physiological development, may lose this affinity for the bottom as they become pelagic and more evenly distributed within the water column and thus more susceptible to guidance by submersible traveling screens (STS).

Studies on gill Na^+-K^+ ATPase activity (Rondorf et al. 1985, 1988; Zaugg 1985; Swan et al. 1987; Muir et al. 1988) have shown that enzyme activity increases during downstream migration. The close proximity of Bonneville Dam to several large fish hatcheries (Carson, Little White, and Spring Creek) influences the makeup of the population at Bonneville Dam. Early in the outmigration, the yearling chinook salmon population passing through the Second Powerhouse is likely dominated by these local stocks which have not yet had time to become fully smolted. Unfortunately, FGE testing was not conducted early in the outmigration because of the release of these local stocks. As a consequence, our gill samples were collected over a short time period (2-16 May) at the Second Powerhouse and excluded early sample dates which we suspect may have exhibited lower gill Na^+-K^+ ATPase levels. The lowest gill Na^+-K^+ ATPase level observed was in a vertical distribution test conducted on 26 April, before FGE testing began. Perhaps the correlation between FGE and smoltification status in yearling chinook salmon at Bonneville Dam would have been stronger if it were possible to sample earlier in the outmigration.

There was no apparent correlation between FGE and smoltification status for coho salmon. One possible explanation is that gill samples from coho salmon were also obtained over a short time period (15 May-1 June) under varying test conditions at the Second Powerhouse, and their smoltification status changed very little during this time. Furthermore, most of the coho salmon arriving at the dam are released from hatcheries situated on the Bonneville pool, and the smolts might not be expected to exhibit pronounced physiological change over such a short migratory distance.

CONCLUSIONS

1. There was no significant correlation between smoltification status and FGE, TFGE, or guidance device effectiveness at either powerhouse for yearling chinook, subyearling chinook, or coho salmon. However, changing test conditions and in some cases the restricted sampling period, made isolation of this possible relationship difficult.

2. Early in the outmigration, yearling chinook salmon which were more advanced in their parr/smolt transformation appeared more susceptible to guidance by an STS. Early in the outmigration, levels of gill Na^+-K^+ ATPase (a measure of smoltification) were significantly higher in guided than in unguided fish at Bonneville Dam Second Powerhouse. However, this relationship was not apparent later in the outmigration when both guidance and gill Na^+-K^+ ATPase levels were higher.

3. Comparison of gill Na^+-K^+ ATPase levels between guided and unguided coho salmon and guided and unguided subyearling chinook salmon were inconclusive.

4. Condition factor is not a reliable index of smolt development for evaluating FGE data, since accurate length measurements are difficult to achieve because candal fins are split and frayed while residing in the fyke nets.

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Appendix Table 1.--Gill Na^{+}-K^{+} ATPase ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) data for yearling chinook salmon from FGE tests at Bonneville Dam, Second Powerhouse, 1988. Means ($\bar{x}$), standard deviation (SD) and sample sizes (u) are presented.

Date		Gatewell	Closure net	Fyke nets 1	2	3	4	5
2 May	$\bar{x}$	29.8	28.4	26.0	22.5	24.4	19.3	29.0
	SD	6.77	7.51	6.78	7.40	7.04	7.11	1.70
	n	19	20	18	20	20	9	2
3 May	$\bar{x}$	31.1	29.0	23.4	25.8	26.0	22.8	34.0
	SD	6.56	9.11	8.99	8.11	6.02	9.77	-
	n	20	20	20	20	20	17	1
9 May	$\bar{x}$	24.8	23.1	32.2	28.6	27.5	25.9	-
	SD	7.49	8.79	-	8.35	9.45	1.82	-
	n	20	13	1	20	19	3	0
10 May	$\bar{x}$	27.8	28.8	29.8	28.4	20.4	25.1	32.6
	SD	7.44	9.49	-	8.32	7.50	8.42	-
	n	19	13	1	20	20	4	1
15 May	$\bar{x}$	29.7	36.5	-	34.3	36.7	20.7	29.0
	SD	7.60	6.55	-	12.07	6.87	0.50	-
	n	20	13	0	20	20	2	1
16 May	$\bar{x}$	32.9	28.5	35.4	32.3	29.6	30.0	29.8
	SD	7.94	6.07	10.63	7.87	7.23	6.35	-
	n	20	20	5	20	20	6	1

Appendix Table 2.--Gill Na^{+}-K^{+} ATPase (µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) data for coho salmon from FGE tests at Bonneville Dam, Second Powerhouse, 1988.

Date		Gatewell	Closure net	Fyke nets 1	2	3	4	5
15 May	$\bar{x}$	19.3	27.0	-	25.9	22.1	21.2	-
	SD	7.00	12.00	-	11.30	8.62	1.53	-
	n	20	8	0	16	10	4	0
16 May	$\bar{x}$	19.4	22.8	-	28.2	21.1	37.2	-
	SD	6.36	9.66	-	12.55	6.59	10.62	-
	n	20	18	0	20	20	3	0
26 May	$\bar{x}$	23.7	18.6	-	18.7	16.8	21.6	-
	SD	6.51	6.90	-	7.91	6.58	13.09	-
	n	20	9	0	13	11	6	0
31 May	$\bar{x}$	25.3	20.9	17.7	20.3	20.4	21.7	24.6
	SD	5.79	4.39	2.12	3.21	3.58	3.98	8.24
	n	20	20	2	10	4	7	3
1 June	$\bar{x}$	18.3	24.1	20.9	21.8	23.7	21.0	-
	SD	3.21	4.24	-	6.67	3.70	7.14	-
	n	20	5	1	8	3	2	0

Appendix Table 3.--Gill Na^+-K^+ ATPase (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) data for subyearling yearling chinook salmon from FGE tests at Bonneville Dam, First Powerhouse, 1988.

Date		Gatewell	Closure net	Fyke nets			
				1	2	3	4
6 Jul	$\bar{x}$	45.6	36.3	39.1	38.8	37.3	38.4
	SD	8.49	13.25	10.67	7.29	9.68	9.20
	n	20	20	15	20	20	20
8 Jul	$\bar{x}$	35.9	34.3	38.1	43.6	42.1	38.0
	SD	10.20	4.48	5.70	7.96	6.53	8.43
	n	20	20	11	20	20	20
18 Jul	$\bar{x}$	36.6	33.9	38.9	32.4	29.4	31.4
	SD	6.22	4.59	9.75	4.35	6.99	8.11
	n	20	17	13	18	20	20
19 Jul	$\bar{x}$	37.2	31.5	34.4	33.5	32.5	35.8
	SD	10.06	7.47	5.30	4.79	9.22	8.96
	n	20	20	7	13	20	20
25 Jul	$\bar{x}$	29.9	32.0	27.7	32.4	35.4	32.0
	SD	6.84	9.21	6.04	5.99	6.47	7.33
	n	20	20	20	20	20	20
26 Jul	$\bar{x}$	26.0	35.2	32.7	33.5	31.2	31.5
	SD	7.69	9.42	7.19	9.87	5.64	6.39
	n	20	10	4	19	20	20

Appendix Table 4.--Gill Na^{+}-K^{+} ATPase ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) data for subyearling yearling chinook salmon from FGE tests at Bonneville Dam, Second Powerhouse, 1988.

Date		Gatewell	Closure net	Fyke nets				
				1	2	3	4	5
6 Jul	$\bar{x}$	39.9	43.9	36.5	37.7	36.7	38.8	32.3
	SD	8.13	6.11	9.73	7.56	5.96	7.25	7.66
	n	20	20	13	12	20	20	3
7 Jul	$\bar{x}$	40.0	44.8	-	39.5	40.3	41.8	49.1
	SD	9.04	7.29	-	7.30	9.18	8.75	5.50
	n	20	20	0	20	17	13	3
18 Jul	$\bar{x}$	30.6	35.9	32.6	40.1	41.5	37.0	39.0
	SD	7.68	7.07	8.73	7.11	10.42	9.84	7.54
	n	20	20	12	20	20	19	10
19 Jul	$\bar{x}$	32.0	24.7	27.3	32.7	23.9	35.3	-
	SD	7.40	4.74	7.52	9.06	5.21	7.21	-
	n	20	20	6	19	14	3	0
25 Jul	$\bar{x}$	28.0	32.3	27.9	29.6	30.8	35.6	45.4
	SD	5.71	8.52	4.86	5.19	6.56	8.68	7.79
	n	20	20	9	20	20	11	6
26 Jul	$\bar{x}$	33.1	26.9	34.5	34.7	28.8	32.9	-
	SD	8.25	7.18	4.85	4.93	5.88	11.89	-
	n	20	19	6	10	15	8	0

Appendix Table 5.--Gill Na^{+}-K^{+} ATPase (μmol $P_i \cdot$ mg Prot $^{-1} \cdot h^{-1}$) data for yearling chinook salmon from vertical distribution tests at Bonneville Dam, Second Powerhouse - 1988.

Date		Gatewell	Fyke nets						
			1	2	3	4	5	6	7
26 Apr	$\bar{x}$	21.0	21.2	22.2	22.3	23.7	28.5	23.5	23.6
	SD	3.29	5.18	4.64	2.87	5.90	5.45	5.61	4.56
	n	20	20	20	20	20	17	15	6
17 May	$\bar{x}$	32.5	28.8	37.1	32.7	26.9	32.6	33.3	23.1
	SD	6.05	7.36	8.25	9.41	5.89	7.80	8.61	-
	n	20	7	14	18	15	18	12	1

Appendix Table 6.--FGE results, number of fish captured in the gatewell and fyke nets (n), and test conditions at Bonneville Dam, Second Powerhouse during smoltification studies - 1988.

Date	PH/unit	Test conditions	Species	n	FGE (%)
2 May	2/12B	30" lowered STS	Yr. chin.	406	32.3
3 May	2/12B	30" lowered STS	Yr. chin.	463	31.7
9 May	2/12B	30" lowered Bar screen	Yr. chin.	184	53.3
10 May	2/12B	30" lowered Bar screen	Yr. chin.	172	43.0
15 May	2/12B	30" low. Bar sn.,4 ceil.light	Yr. chin.	178	52.8
16 May	2/12B	30" low. Bar sn.,4 ceil.light	Yr. chin.	334	57.5
15 May	2/12B	30" low. Bar sn.,4 ceil.light	Coho	219	75.3
16 May	2/12B	30" low. Bar sn.,4 ceil.light	Coho	449	68.8
26 May	2/12B	30" low. Bar sn.,4 ceil.light	Coho	210	68.1
31 May	2/12B	30" low. Bar sn.,Hg. vapor light	Coho	316	58.9
1 June	2/12B	30" low. Bar sn.,Hg. vapor light	Coho	110	50.0
6 July	2/12B	30" low. Bar sn.	Sub. chin.	941	49.4
7 July	2/12B	30" low. Bar sn.	Sub. chin.	543	46.8
18 July	2/12B	30" low. Bar sn.	Sub. chin.	656	24.5
19 July	2/12B	30" low. Bar sn.	Sub. chin.	335	35.8
25 July	2/12B	30" low. Bar sn.,ceil.& BS lts.	Sub. chin.	415	27.5
26 July	2/12B	30" low. Bar sn.,all lights	Sub. chin.	384	50.3