FRED Reports

EFFECTS OF SUPPLEMENTARY DIETARY SALT
ON
CHINOOK SALMON
AT DEER MOUNTAIN HATCHERY

by
Carol Denton
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ABSTRACT

A group of 150,000 spring chinook salmon, *Oncorhynchus tshawytscha*, at Deer Mountain Hatchery were fed salt-supplemented ADP-3 for an 8-week period, beginning 4 months after emergence. A 1-week saltwater-rearing period immediately followed the diet. All fry were released from the saltwater pens by 29 June. A control group of 150,000 fry was similarly reared and fed standard ADP-3.

Saltwater challenge tests conducted every 2 weeks during administration of the salt-supplemented diet showed blood-sodium levels generally - but not consistently - lower in the experimental group. An average value below 170mM/liter was never recorded. Survival during saltwater-challenge tests for the experimental group peaked at 63% after 4 weeks of the diet and declined to 19% after 8 weeks. Survival for the control group tested in saltwater increased from 40% after 4 weeks to 80% after 8 weeks. Average fork length of survivors was generally 10 mm greater than that of the mortalities from all test groups.

Growth in the salt-supplemented group lagged until early June; then it exceeded the control group. At time of release, salt-supplemented fish averaged 6.5 g (82 mm), and the control group averaged 5.9 g (78 mm). Conversion was better in the control group. Thirty thousand fish from each group were coded-wire tagged prior to release.

KEY WORDS: *Oncorhynchus tshawytscha*, smolting, salt diet.

INTRODUCTION

This report covers the rearing phase of an experiment at Deer Mountain Hatchery to assess marine survival of spring chinook salmon, *Oncorhynchus tshawytscha*, that were fed supplemental dietary salt. The experiment is part of the age-zero (smolts less than 1 year old) release program at Deer Mountain.

Previous work in Washington (Zaugg et al. 1983) showed that feeding supplemental salt to fry resulted in a 65% greater adult return of fall chinook salmon. Marine survival of coho salmon, *Oncorhynchus kisutch*, has been shown to increase with this same treatment (Zaugg and McLain 1969).

MATERIALS AND METHODS

The 1983 brood chinook salmon fry involved in this experiment emerged from Heath Tray incubation units in mid-December 1983 at an average weight of approximately 0.5 g. They were reared in 1.8-m Swedish-style fiberglass ponds inside the hatchery building until 21 February 1984. Then they were transferred outside to two concrete raceways that measured approximately 5.2 x 10.7 m; the raceways were divided longitudinally by a concrete wall.

Beginning 24 April, 153,920 fish in one raceway were given ADP-3 feed, to which the manufacturer had been directed to add 7% NaCl. Approximately 172,500 fish in the other raceway received ADP-3 with no salt added. These diets were continued for an 8-week period.

Average wet weights of 150 fish and lengths of 50 fish were calculated every 2 weeks for both groups. From 24 April through 29 June, saltwater-challenge tests (Clarke and Blackburn 1977) were conducted every two weeks, using either a solution of "Marine Environment"[1] (at 29 0/00 salinity) or ambient salt water (24-27 0/00) that had been raised to 29 0/00 salinity with

"Marine Environment". Blood samples were collected at the hatchery and analyzed by personnel at Ketchikan General Hospital Laboratory. Most samples included blood from more than one fish whose lengths fell within a 4-mm range. Sample labels included median fish length. Approximately 30,000 fish from the salt-supplemented group and 30,000 fish from the control group were coded-wire tagged during this period.

All fish were transferred to saltwater-rearing pens at the mouth of Ketchikan Creek on 21 June. Rearing continued with unsalted feed until portions of each group were released on 27 June; the remainder were released on 29 June 1984.

RESULTS AND DISCUSSION

Saltwater Adaptation

The results obtained in this study do not correspond well with previous results using fall chinook in Washington State (Zaugg et al. 1983). In the present study, survival of fish chosen to be challenged by salt water peaked on 23 May and then declined in subsequent tests of the salt-supplemented group. Survival for the challenged fish in the control group generally increased over the 8-week period (Table 1). Smaller individuals in all groups had lower survival in saltwater-challenge tests, indicating that osmoregulatory capability develops with increasing size. It is unclear, however, why smaller ($\bar{x}$ = 62 mm) fry survived the challenge on 23 May, while larger ($\bar{x}$ = 68 mm) fry did not survive on 20 June.

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[1] Manufactured by Brig-O-Dune Company

Table 1. Survival during saltwater challenges of spring chinook salmon in dietary salt experiment, Deer Mountain Hatchery.

Date & Group	Percent surviving challenge	$\bar{x}$ length (S.D.), mm		
		Survivors	Mortalities	Population[1]
25 April				
NaCl	0	-	49 (5)	53 (4)
Control	0	-	46 (5)	53 (4)
9 May				
NaCl	0	-	51 (4)	57 (4)
Control	0	-	51 (4)	58 (4)
23 May				
NaCl	63	62 (4)	52 (5)	62 (6)
Control	40	63 (4)	53 (7)	64 (4)
6 June				
NaCl	38	68 (4)	59 (6)	67 (6)
Control	39	71 (5)	61 (6)	66 (7)
20 June				
NaCl	19	76 (4)	68 (6)	75 (6)
Control	80	78 (5)	67 (5)	77 (6)

[1] Representative live sample from entire experimental group.

Plasma sodium levels following saltwater challenge tests were lower for the salt-supplemented group, with the exception of the 6 June sample (Figure 1). None of the average levels obtained were below 170mM/liter, the value that would indicate a fully-smolted fish, according to Clarke and Blackburn (1977). Some individual readings below 170mM/liter were obtained after 9 days of saltwater rearing at 24-25 0/00 salinity (Figures 2a and 2b). Lowest individual readings for the 6, 20, and 29 June samples were from the control group. Average length in both groups was greater than 65 mm by 5 June; 65-70 mm is the generallly accepted minimal size necessary to achieve osmoregulatory capability. Apparently, the additional dietary salt had no consistent, positive influence on osmoregulatory capability.

Growth

Rate of growth for the salt-supplemented group was less than that of the control group until early June (Figure 3). The salt-supplemented fish averaged 0.6 g larger than control group fish at time of release. Less efficient food conversion was noted for the salt-supplemented group during administration of the salty diet (Figure 3 and Table 2). Similar results have been reported from other studies (Zaugg and McLaine 1969; Westgate et al. 1976).

A proximate analysis of feed samples from the Deer Mountain study was done by United State Fish and Wildlife Service's Fish Technology Center[1]. Table 3 gives these values as well as the

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[1] Beulah, Wyoming.

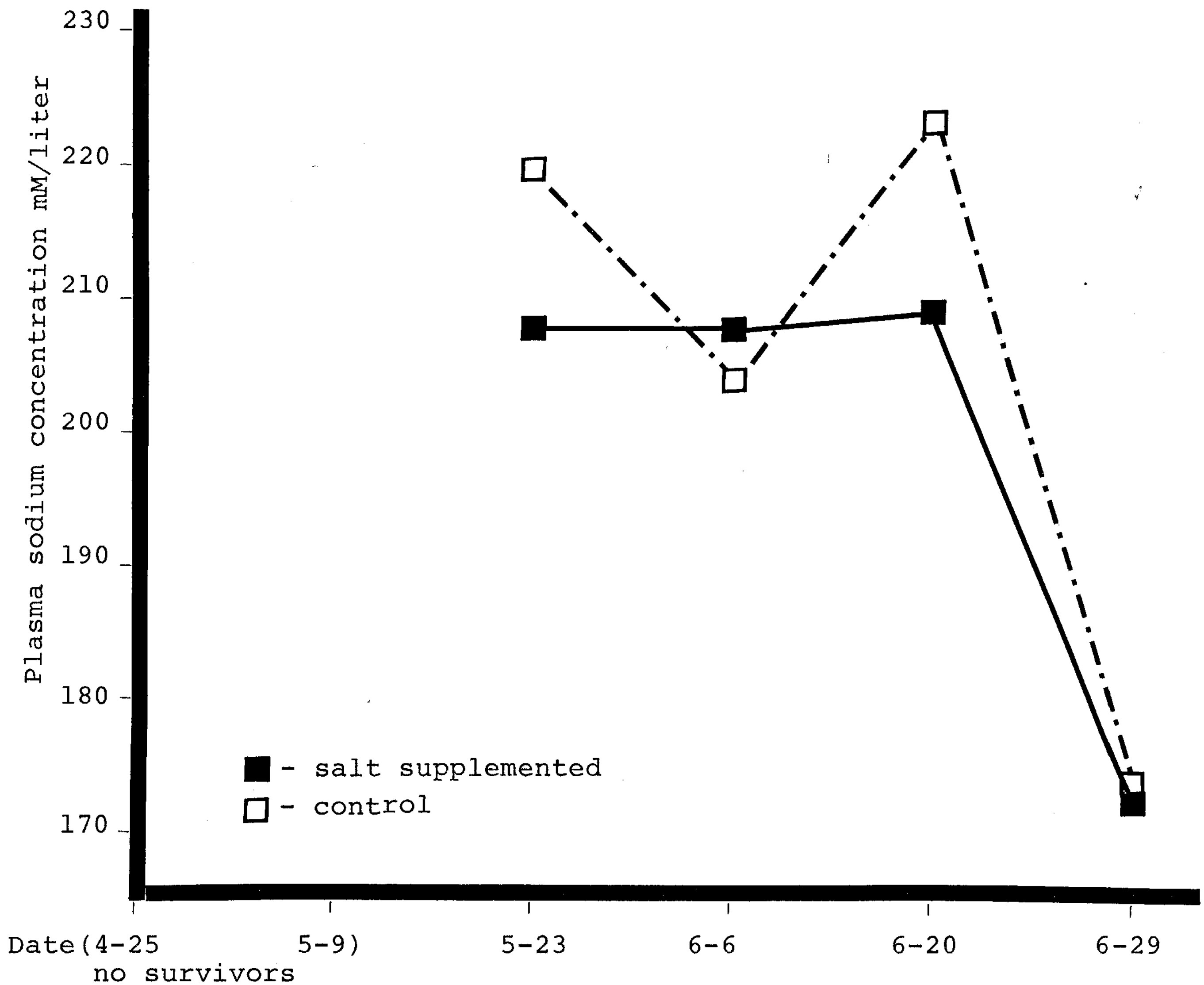

Figure 1. Average plasma sodium levels following saltwater challenges of spring chinook salmon in dietary salt experiment, Deer Mountain Hatchery.

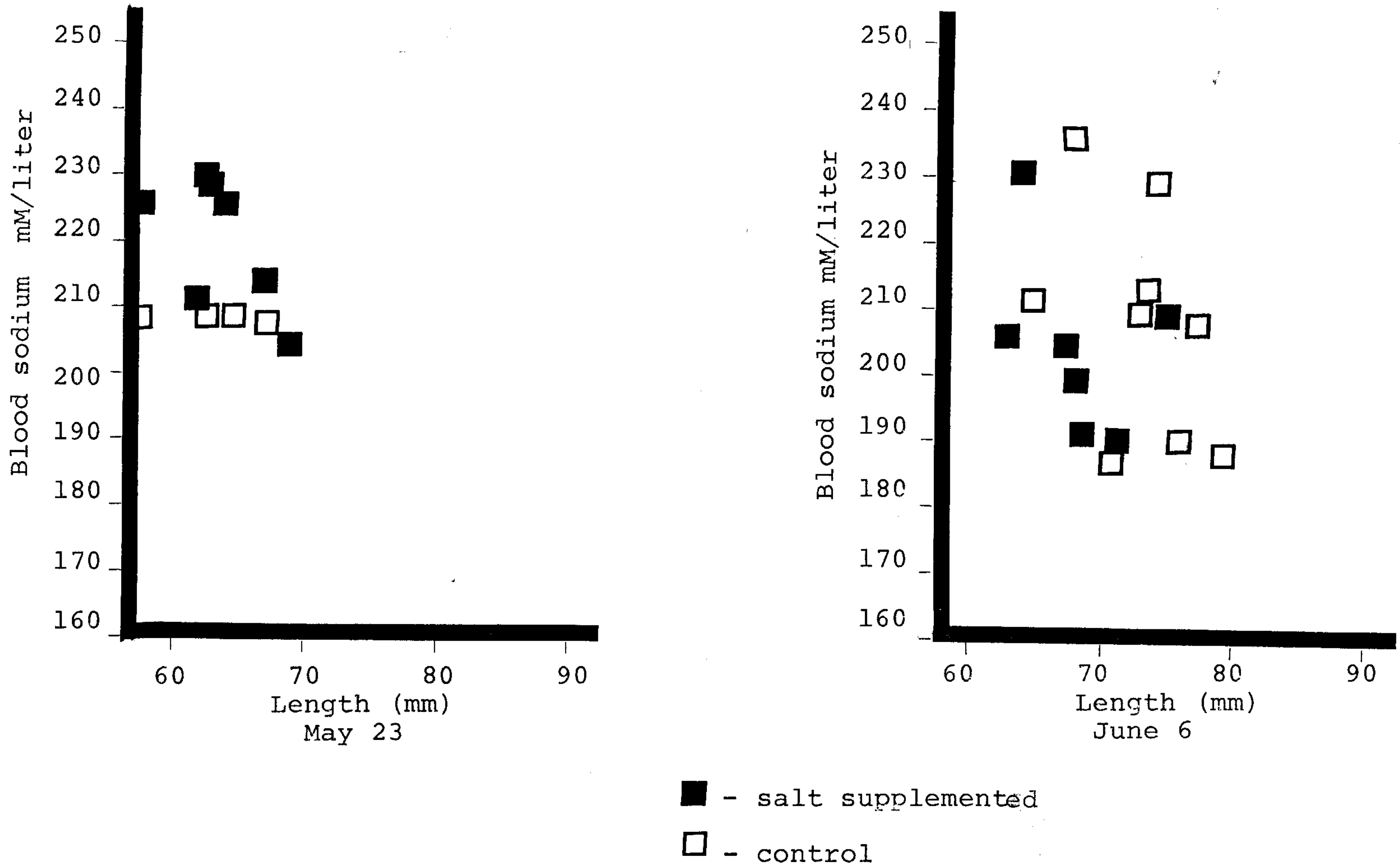

Figure 2a. Fish length plotted against plasma sodium level following saltwater challenge tests, Deer Mountain Hatchery.

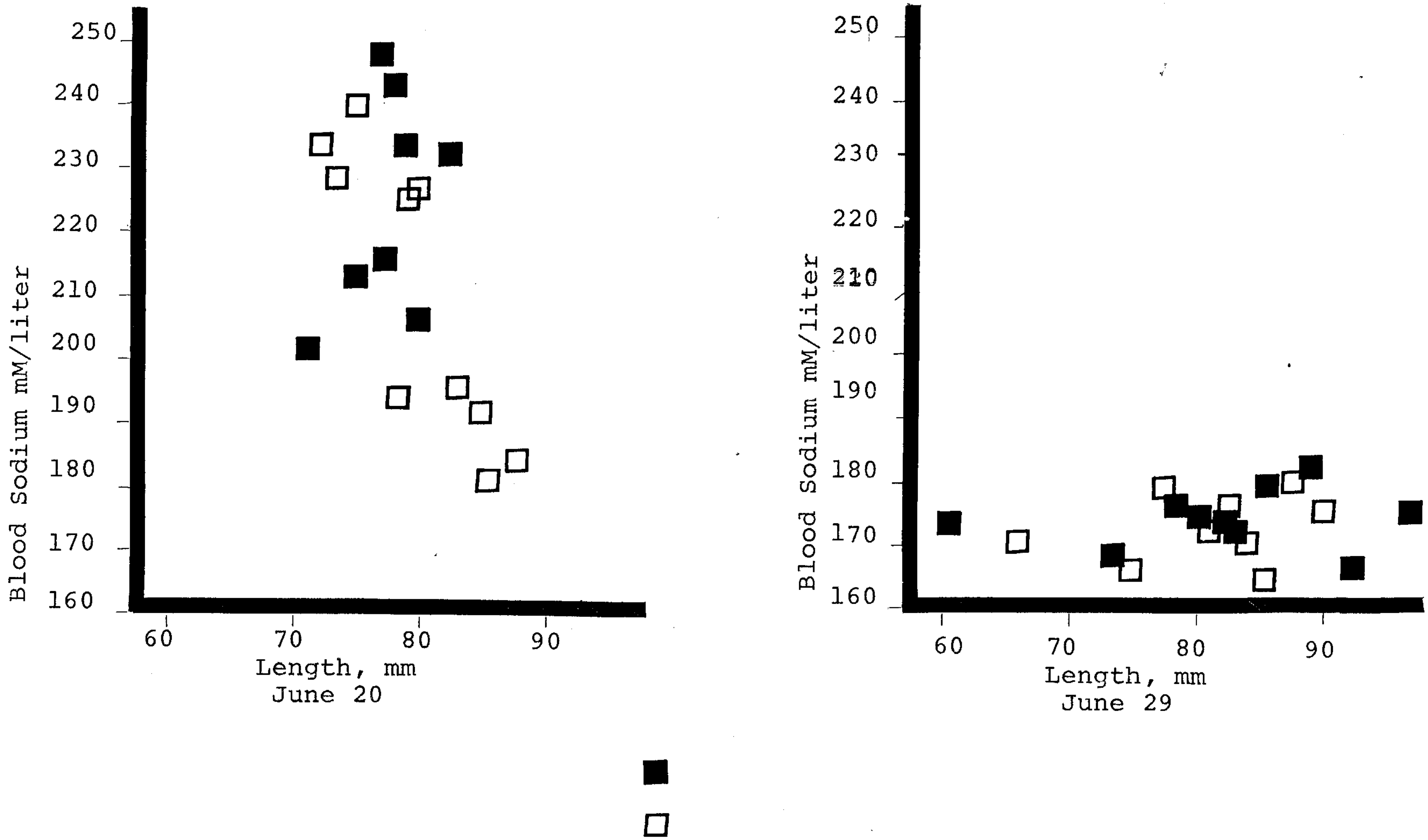

Figure 2b. Fish length plotted against plasma sodium level following saltwater challenge tests, Deer Mountain Hatchery.

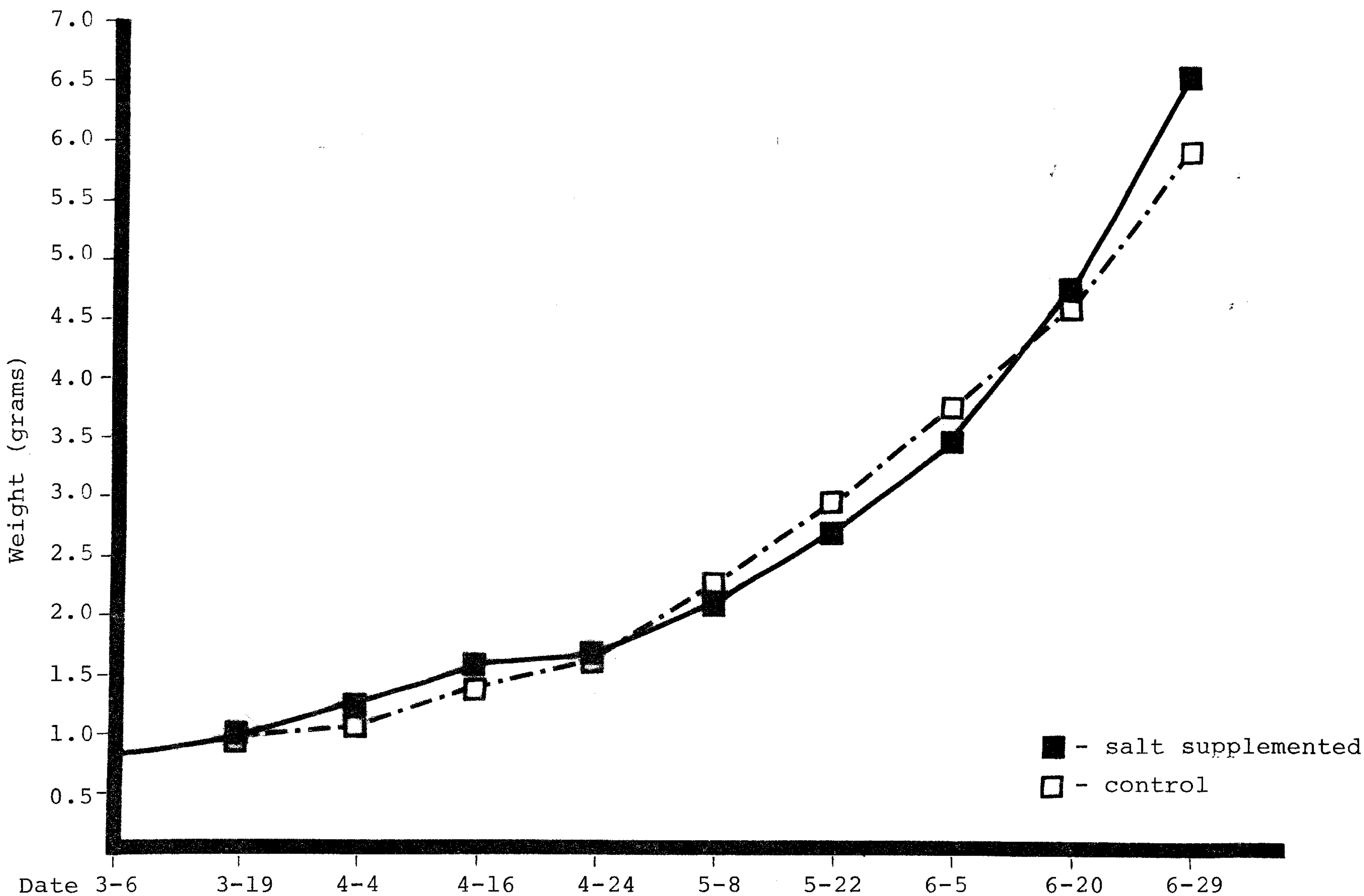

Figure 3. Average fry weight, dietary salt experiment, Deer Mountain Hatchery, 1984.

Table 2. Food conversion indices for chinook salmon fed ADP-3 with or without supplemental salt at Deer Mountain Hatchery.

Date (period ending & group)	Conversion [a]
19 March - NaCl	1.43
Control	1.10
4 April - NaCl	1.15
Control	4.25 [b]
16 April - NaCl	1.05
Control	0.64
24 April - NaCl	2.82
Control	1.01
8 May - NaCl	1.23
Control	0.72
22 May - NaCl	1.13
Control	0.96
5 June - NaCl	1.15
Control	1.00
20 June - NaCl	0.89
Control	1.09
29 June - NaCl	0.66
Control	0.77
$\bar{x}$ NaCl samples	1.28
$\bar{x}$ Control samples	0.91 [c]

[a] Dry weight of food fed divided by wet weight of fish gained.

[b] Sampling error suspected for control group on 4 April.

[c] Excludes 4 April sample.

Table 3. Analyses of ADP-3 feed used in dietary salt experiment, Deer Mountain Hatchery.

Feed Type	Protein	Fat	Moisture	Ash	Salt
ADP-3 [a]	57.3	14.0	9.8	12.6	1.5
ADP-3 + Salt [a]	48.1	16.1	17.7	15.4	6.0
ADP-3 [b]	56.0	15.6	11.7	13.8	[c]

[a] Analysis by Fish and Wildlife Service Beulah Fish Technology Center, Beulah, Wyoming.

[b] Analysis by National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle.

[c] Not determined.

results of a proximate anaylsis of ADP-3 by the National Marine Fisheries Service during another experiment[1]. It is evident that the added salt caused moisture absorption, resulting in relatively less nutrient content per unit weight. Also, the presence of additional salt reduced the caloric density of the food. These factors may have contributed to poorer growth in the salt-supplemented group. Reduced palatability may also have been a factor. Westgate et al. (1976) found poorer growth and conversion with increased salt content of OMP, even though moisture content did not increase with increased salt content.

Sources of Error

Some problems emerged during this experiment that probably affected the outcome. Increased mortality of unknown cause was a problem during April and May. Clinical signs were emaciation, minor flashing, dark material in intestinal lumen, pale liver, and dark fecal casts. Tests for *Renibacterium salmonarum*, *Aeromonas salmonicida*, and necropsy as well as a parasitological exam and bacterial culture were completed at Fisheries Rehabilitation, Enhancement and Development (FRED) Division's Fish Pathology Section in Anchorage. All tests proved negative[2]. A histological exam showed unidentified basophilic cells in the intestinal lumen and in loose connective tissue and fat of the intestinal serosa. Pathology Section personnel state that these cells appear to be related to the cause of the mortality. Treatment of small groups of fry with Epsom salt, diquat, or TM-50 failed to show any improvement.

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[1] Northwest and Alaska Fisheries Center, Seattle.

[2] Fish Health Record, Accession Number 840229.

An analysis of water samples taken 13 June in the raceway showed a zinc content (.005 mg/liter[1,2]) that was by FRED standards unacceptable. If this level of zinc was present in rearing water during April and May, it may have been toxic over this extended period of time; or it may have interfered with one or more metabolic processes, allowing susceptibility to a pathogen or parasite. A recheck of the water supply and an investigation into the cause of contamination is currently underway (May 1985).

Previous work reported by Zaugg et al. (1983) does not indicate the minimal salt content of feed needed to produce the effect of increased survival. Feed used in their studies contained 8.0% to 9.0% total salt; the salt-supplemented ADP-3 used in this study apparently had 6.0% total salt (*see* Table 3). It is possible that this salt content was below the threshold level needed to produce any benefit.

All fry in this study were re-counted (using a biomass estimate) when they were transferred to saltwater-rearing pens. This count was considerably different than the count used for ration calculations during the freshwater-rearing phase. The original counts from the fry counter at time of emergence were 13% (salt-supplemented group) and 28% (control group) lower than numbers obtained by biomass estimate. It is likely that the softness of the Deer Mountain Hatchery water supply caused a malfunction of the fry counter, resulting in the inaccurate count. This means that the control group was consistently fed at a lower percent body weight than the salt-supplemented group.

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[1] Water analysis by Lauck's Testing Laboratories, Inc., Seattle.

[2] Fish Culture Manual/By FRED Staff. 1983

Nevertheless, the control group had better growth and conversion during most of the study. The difference in conversion rates may indicate overfeeding in the salt-supplemented group as well as the previously mentioned problems associated with the salt. All fry numbers used in this report have been back-calculated from the biomass estimate. Actual percent fed, conversions, and instantaneous mortality rates (*see* Appendix Table 1) are also back-calculations.

Results from the in-hatchery phase of this experiment do not support the hypothesis that a salt-supplemented diet facilitates seawater adaptation for spring chinook salmon under the environmental conditions of the Deer Mountain Hatchery and nearby marine waters. No advantage was seen in immediate survival or plasma-sodium regulations. Estimates of comparative marine survival of the two groups will indicate any efficacy of the salt levels fed in this study.

Some obvious experimental design differences from the previous studies reported by Zaugg et al. (1983) are as follows:

1. Spring chinook rather than fall chinook were used at Deer Mountain.

2. There were differences in fish age and size at the start of feeding the salt-supplemented diets: Spring Creek - 72 days, 66 mm; Deer Mountain - 124 days, 53 mm; Garrison Springs - 204 days, 107 mm.

3. Average water temperature was probably colder at Deer Mountain than at Spring Creek, as indicated by the slower growth at Deer Mountain.

4. Lower levels of salt were used in diets at Deer Mountain Hatchery than at the other facilities.

Blood-sodium levels suggest that the 15-mm-longer 0-age 1983 release group, unlike the smaller 1984 release group, were physiological smolts.[1]

A repeat of this experiment would be worthwhile. In addition to eliminating the obvious sources of error, the following might be helpful:

1. Use of two or more replicates per group.

2. Use of local saltwater (≅ 25 to 27 0/00 salinity) for challenge tests.

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[1] Mike Ward, FRED Division, Ketchikan, personal communication.

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The author thanks David Bright and the Deer Mountain Hatchery staff for their cooperation and diligence in carrying out this project. Some information used in this report is from fish food analyses provided by Northwest and Alaska Fisheries Center (National Marine Fisheries Service), Seattle, and Fish and Wildlife Services Fish Technology Center, Beulah, Wyoming. Dr. John S. Holland provided technical assistance. Dr. Kenneth Leon and Dr. Holland reviewed the manuscript.

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APPENDIX

Appendix Table 1. Deer Mountain Hatchery Growth Record

Group Salt Experiment and Control[a]

Date	Water temp	Weight	Length	K	No. live	Density	Total Last Period[b] T.U.	Feed-g	% Actual	Conversion	Δ Length per T.U.	IGR	IMR
3-6	4.5	0.840	44.66	.0094	157,093	0.284[c]							
		0.808	44.14	.0094	179,226	0.308							
3-19	4.0	1.003	45.74	.0105	156,745	0.339	54	36,110	2.2	1.430	.020	.01364	.00017
		0.989	46.32	.0100	178,949	0.376		35,380	2.0	1.100	.040	.01555	.00012
4-4	4.0	1.287	49.18	.0108	156,402	0.434	69	50,760	2.0	1.152	.050	.01558	.00014
		1.057	46.80	.0103	178,644	0.401		50,370	1.8	4.252	.007	.00416	.00011
4-16	5.0	1.590	50.58	.0123	155,425	0.533	57.5	48,070	2.0	1.049	.024	.01762	.00052
		1.419	49.74	.0115	177,677	0.536		40,350	1.8	0.637	.051	.02454	.00045
4-24	4.5	1.692	52.88	.0114	153,920	0.561	39	37,540	2.0	2.821[g]	.060	.00777	.00122
		1.650	52.80	.0112	172,507	0.605		32,940	1.8	1.013	.078	.01885	.00369
5-8	6.5	2.115	56.58	.0117	150,184	0.520[d]	87	70,220	2.2	1.227	.043	.01594	.00176
		2.292	58.10	.0117	165,564	0.612		67,800	1.9	0.715	.060	.02347	.00083
5-22	6.5	2.714	61.98	.0114	148,170	0.658	96	95,840	2.6	1.134	.056	.01781	.00096
		2.961	63.56	.0115	164,108	0.784		102,300	2.4[e]	0.961	.057	.01829	.00064
6-5	8.5	3.476	66.80	.0117	144,006	0.819	105.5	112,740	2.6	1.145	.046	.01768	.00204
		3.759	65.56	.0133	163,131	0.989		126,860	2.4	0.997	.019	.01704	.00043
6-20	10.0	4.755	75.06	.0112	139,744	1.087	139.25	145,550	2.3	0.888[h]	.059	.02089	.00200
		4.605	76.82	.0102	165,017	1.226		159,680	2.1	1.089	.081	.01353	.00119
6-29	11.0	6.530	82.28	.0117	139,402	0.182/0.196[f]	100	163,060	3.4	0.663	.072	.03525	.00027
		5.930	78.44	.0123	164,646	0.177/0.229		167,230	3.4	0.773	.016	.02810	.00025
Coded wire tag codes:		salt group - 04-23-02.				Control group - 04-23-57.							

[a] First entry for each date = salt group, 2nd entry = control

[b] Includes day of previous sample but not day of present sample

[c] Water level 3'5" - volumes = 1022.76 & 1037.65

[d] Water level 4'6" - volumes = 1347.047 & 1366.664

[e] Medicated feed - start 5-15

[f] Final densities, Tess pens

[g] Begin salt diet 4-24

[h] End salt diet 6-20