CZES Coastal Zone and Estuarine Studies

A Study to Assess Status of Smoltification and Fitness for Ocean Survival of Chinook and Coho Salmon and Steelhead

by
Earl F. Prentice, Conrad Mahnken, Kurt Gores, William Waknitz,
Waldo Zaugg, Leroy Folmar, Robert King, James Mighell,
Walter Dickhoff, Thomas Flagg, Lee Harrell, Anthony Novotny,
David Damkaer, Einar Wold, and Robert Vreeland

September 1980

FY-1979-80 SUMMARY REPORT

FOR

PROJECT 10990060

A STUDY TO ASSESS STATUS OF SMOLTIFICATION AND FITNESS FOR OCEAN SURVIVAL OF CHINOOK AND COHO SALMON AND STEELHEAD

by

Earl F. Prentice, Conrad Mahnken, Kurt Gores, William Waknitz, Waldo Zaugg, Leroy Folmar, Robert King, James Mighell, Walter Dickhoff, Thomas Flagg, Lee Harrell, Anthony Novotny, David Damkaer, Einar Wold, and Robert Vreeland

Coastal Zone and Estuarine Studies Division
NOAA
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

and

Environmental and Technical Services Division
NOAA
National Marine Fisheries Service
Northwest Regional Office
P.O. Box 4332
Portland, Oregon 97208

September 1980

CONTENTS

APPENDIXES

A SMOLTIFICATION STATUS, OCEAN SURVIVAL, AND GILL Na^+-K^+ ATPase ACTIVITIES IN SALMONIDS

B SEAWATER ADAPTATION OF COHO, SPRING, AND FALL CHINOOK SALMON, AND STEELHEAD

C INFLUENCE OF SEAWATER TEMPERATURE ON SURVIVAL, STATUS OF SMOLTIFICATION, AND EXTERNAL DARKENING OF STEELHEAD

D FISH HEALTH, A GENERAL EVALUATION

E FRESHWATER GROWTH AND SMOLTING CHARACTERISTICS OF TOUTLE COHO SALMON REARED FOR BASELINE DATA COMPARISON

F COMPARISON OF PHYSIOLOGICAL CHANGES ASSOCIATED WITH SMOLTIFICATION AND SEAWATER ADAPTATION IN THREE SPECIES OF ANADROMOUS SALMONIDS

G CHANGES IN SWIMMING STAMINA AND SWIMMING FATIGUE SURVIVAL IN RESPONSE TO DIRECT SEAWATER ENTRY DURING THE PARR-SMOLT TRANSFORMATION FOR COHO SALMON

INTRODUCTION

In 1978, the National Marine Fisheries Service (NMFS), cooperating with the Pacific Northwest Regional Commission (PNRC), initiated a 3-year study to assess the status of smoltification and fitness for ocean survival of chinook (Oncorhynchus tschawytscha), and coho salmon (O. kisutch), and steelhead (Salmo gairdneri). The study evaluates various factors believed to influence smoltification, ocean survival, and adult return of anadromous salmonids from hatcheries on the Columbia River and its tributaries.

This preliminary summary report discusses progress during the second year of the study. Final results, conclusions, and recommendations await completion of the study in 1981.

The specific objectives of the study are as follows:

1. Determine the status of smoltification in fish from selected hatcheries prior to release using gill Na^{+}-K^{+} ATPase activity, plasma thyroid hormone concentrations, and plasma electrolyte concentrations in addition to traditional external morphological and behavioral criteria.

2. Determine seawater adaptability of fish from some of the same hatcheries by monitoring growth, mortality, and reversion to parr in the seminatural conditions of seawater net-pens.

3. Ascertain the general freshwater health profile of fish from each hatchery. Determine the presence of latent freshwater diseases in fish at the hatchery and the susceptibility of fish to disease in seawater net-pens.

4. Develop and evaluate short term tests for determining adaptability to seawater.

Accomplishment of the above objectives will ideally lead to:

1. Development of practical indexing methods for hatchery management personnel to determine the optimal time for fish release.

2. Fish being released at the peak of smoltification, resulting in more rapid outmigration thus reducing competition with wild fish, exposure to predators, and residualism in the river. Rapid passage of the released fish through the estuary would result in early entry into oceanic water where food is more abundant.

3. Better overall survival of juveniles, resulting in greater return of adults to the fisheries and hatcheries.

4. Provide hatchery management agencies with biological data regarding smoltification, outmigration, and seawater adaptation in order to program releases to coincide with favorable biological conditions in the river and ocean environments.

METHODS

The present report encapsulates progress during the second year of study. During the 1979 study, 42 groups of fish from 17 state and federal hatcheries were evaluated in fresh and/or seawater (Table 1 and Figures 1 and 2). Target species included coho salmon, spring and fall chinook salmon, and steelhead. Greater emphasis was placed on chinook salmon in 1979 than in 1978. Selections of hatcheries and test fish were coordinated with the Oregon Department of Fish and Wildlife, Washington Department of Fisheries, Washington Department of Game, and the U.S. Fish and Wildlife Service.

High priorities, as in 1978, were given to tagged groups in existing or planned evaluation programs where two separate stocks were grown under the same environmental conditions, where one stock was grown at two different hatcheries, or where stocks exhibited unique characteristics of growth and adult survival. The coho salmon test groups evaluated were part

Table 1.--Chinook and coho salmon and steelhead test groups for 1979 smoltification and seawater adaptability study.

Hatchery	Stock	Species	Agency	Brood year	Reason for selection	Date of transfer to Manchester month/day/year	Date of seawater entry month/day/year	Number of replicates
Kalama Falls	Kalama Falls	Fall chinook	WDF[1]	1978	OII study[6]-tagged fish	071679	071979	2
Toutle	Green River	Fall chinook	WDF	1978	OII study-tagged fish	062279	062779	1
Bonneville	Snake River	Fall chinook	ODFW[2]	1977	Age 1+ -tagged fish	031579	032079	2
Bonneville	Bonneville	Fall chinook	ODFW	1978	OII study-estuary[7]-tagged fish	052979	053179	2
Little White Salmon	Little White Salmon	Fall chinook	USFWS[3]	1978	OII study-estuary-tagged fish	062279	062779	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	032079	032279	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	041979	042179	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	051879	052279	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	081079	081479	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	071078	071278	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	103078	110178	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	041979	042179	2
Big White Salmon	Spring Creek	Fall chinook	USFWS	1978	OII study-estuary-NMFS homing study-tagged fish	051879	052279	1
Elokomin	Elokomin	Fall chinook	WDF	1978	OII study-tagged fish	061379	061579	2
Washougal	Washougal/Toutle	Fall chinook	WDF	1978	OII study-estuary-tagged fish	061379	061579	2
Carson	Carson	Spring Chinook	USFWS	1977	NMFS homing study-tagged fish	050179	050379	1
Leavenworth	Carson	Spring Chinook	USFWS	1977	Tagged fish	042579	042779	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	050779	050979	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	060779	061079	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	070679	071079	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	050779	050979	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	060779	061079	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	070679	071079	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	050779	050979	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	060779	061079	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	070679	071079	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	050779	050979	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	061379	061679	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	070679	071079	1
Toutle	Green River	Coho	NMFS[4]	1976	Baseline serial entry 1	031579	032079	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 2	032979	040379	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 3	041379	041779	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 4	042779	050179	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 5	051179	051579	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 6	052579	053079	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 7	060879	061279	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 8	072079	072479	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 9	081679	082179	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 10	091679	091879	1
Tucannon	Skamania	Steelhead	WDG[5]	1978	NMFS homing study-tagged fish	051479	051679	1
Chelan	Chelan	Steelhead	WDG	1978	NMFS homing study-tagged fish	042579	042779	1
Wells	Wells	Steelhead	WDG	1978	NMFS homing study-tagged fish	051079	051279	1

1/ Washington Department of Fisheries
2/ Oregon Department of Fish and Wildlife
3/ US Fish and Wildlife Service
4/ National Marine Fisheries Service
5/ Washington Department of Game
6/ NMFS Operational Improvement Investigations
7/ NMFS Estuary Migrant Capture Evaluation study

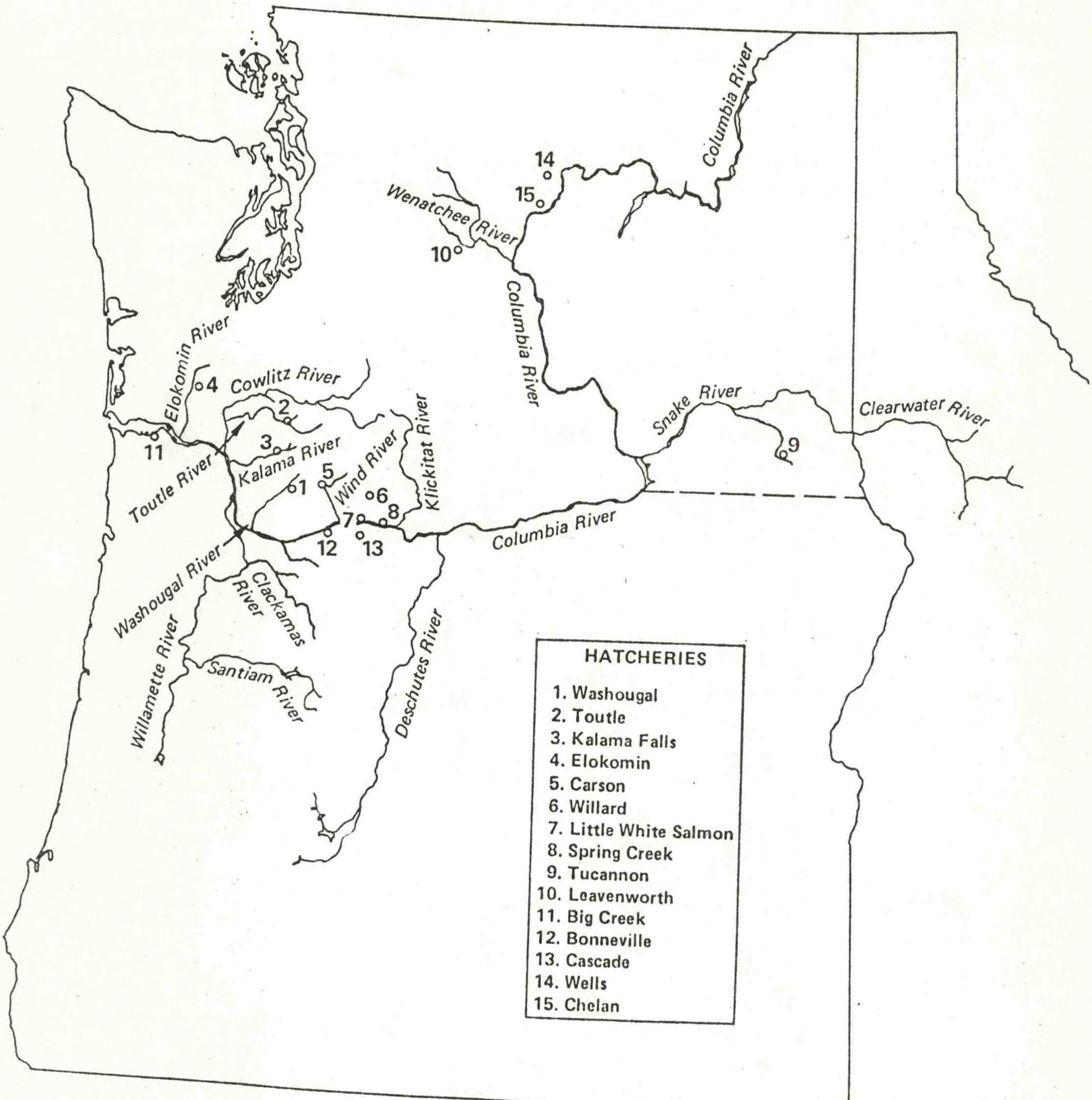


Figure 1.--Location of cooperating hatcheries.

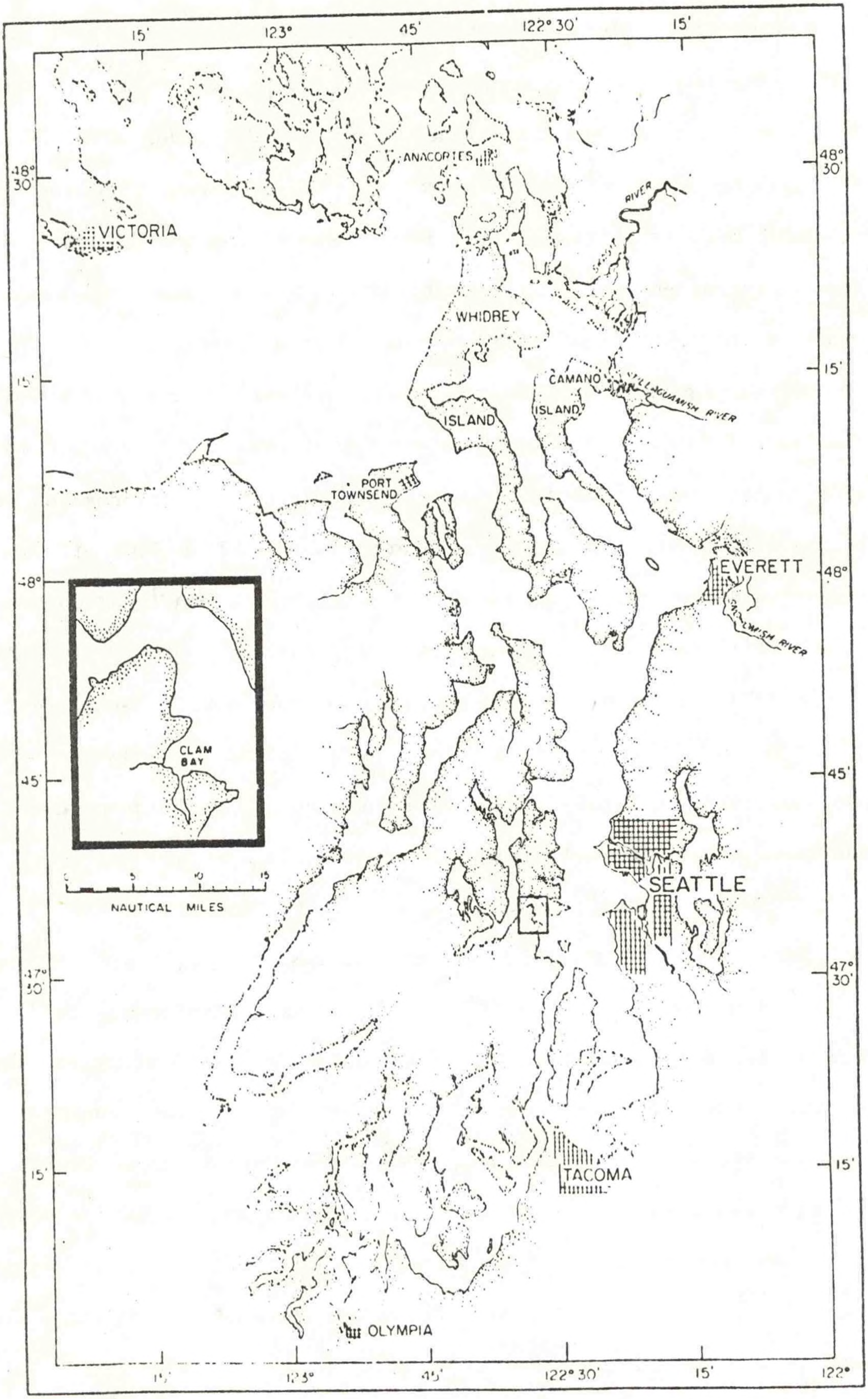


Figure 2.--Location of Manchester seawater test facilities.

of a size-time release study conducted by Oregon and Washington state fishery agencies, at Big Creek, Cascade, Toutle, and Washougal Hatcheries. Fish were released from the hatcheries in May, June, and July. The fish at the time of each release were of a size comparable to the preceding release. The use of tagged fish from studies conducted by other state and federal agencies made it possible to identify our experimental fish captured in the NMFS sampling program at Jones Beach or Clatsop Spit (Study to Define Migrational Characteristics of Chinook and Coho Salmon and Steelhead Trout in the Columbia River Estuary--NMFS-PNRC Project 10990061). Fish so captured provided biochemical and migrational information on active outmigrants. These data were compared to data from fish at the time of release and from fish retained at the hatchery for continued observation.

Detailed methods and materials were presented in the FY 1978-79 report to the PNRC and with few exceptions remain the same. Parameters used to determine status of smoltification, fish health, and seawater adaptation are summarized in Table 2. Specific changes in the various parameters are outlined in Appendixes A through G.

Smoltification Studies at the Hatcheries

Gill Na^+-K^+ ATPase, plasma thyroxine (T_4), triiodothyronine (T_3), monovalent (NA^+, K^+, Cl^-) and divalent (Ca^{++}, Mg^{++}) plasma electrolyte profiles were established for freshwater fish from each of the cooperating hatcheries. In most cases, the sampling periods extended through the normal hatchery release period (Appendixes A and F). The biochemical measurements were compared with the migratory patterns of the fish recovered in the estuary to determine if the status of smoltification at the time of release was related to migration time and seawater survival (Appendixes A and F).

Table 2.--Parameters used to determine status of smoltification, fish health, seawater adaptation, and adult contribution

Study unit	Parameter	Technique
Freshwater smolt status	Gill Na^{+}-K^{+} ATPase	Colorimetric enzyme assay (CEA)
	Thxroxine T_3, T_4	Radioimmune assay (RIA)
	Blood ions Cl^{-}, K^{+}, Na^{+}, Ca^{++}, Mg^{++}	Atomic absorption
	Growth	Hatchery records
	Parr-smolt ratio	Hatchery subsample-visual
	Migration time	Recovery of tagged outmigrants in estuary
Seawater adaptation	Gill Na^{+}-K^{+} ATPase	CEA
	Thyroxine T_3, T_4	RIA
	Blood ion Cl^{-}, K^{+}, Na^{+}, Ca^{++}, Mg^{++}	Atomic absorption
	Survival	Daily counts of mortalities
	Parr-smolt ratios	Monthly counts-visual
	Growth and condition index	Monthly length-weight measurements
	Swimming performance	Performance chamber
	Muscle protein	Electrophoresis
Fresh and seawater diseases	Freshwater disease profiles	Hatchery records
	Hematology (hematocrits and hemoglobin)	Standard hematological methods
	Presence of bacterial disease	Agar plates, post mortems, fluorescent antibody techniques

Fish Health Studies

Histories of freshwater disease, rearing temperature, disease treatment, size at release, and hatchery mortality were compiled from hatchery records (Appendix D). Assays to determine the occurrence and incidence of selected infectious diseases known to affect the growth and survival of salmonid fishes were conducted on fish sampled at the hatcheries.

The evaluation included an assessment of basic hematological parameters (hemoglobin and hematocrit), and bacterial kidney disease (BKD) carrier status. To obtain additional fish health data during seawater adaptation tests, necropsies were performed on recent mortalities or moribund fish.

Seawater Adaptability Studies

At about the time of hatchery release, random samples of fish from the hatcheries were transported to the NMFS Manchester Marine Experimental Station on Puget Sound (Clam Bay) for seawater adaptability testing in nylon net-pens (Table 1, Figure 2). At the time of transfer each fish was weighed, measured (for length), and evaluated for status of smoltification using external characteristics. The measurements and evaluations were repeated every 30-60 days for a period of up to 180 days (Appendix B). An additional test was conducted on a group of steelhead to determine the effect of seawater temperature on adaptation (Appendix C).

Baseline Studies

To develop short-term tests for seawater adaptability and to evaluate the smoltification process of fish reared under known conditions, a group of coho salmon was grown in fresh water at the Northwest and Alaska Fisheries Center's (NWAFC) hatchery in Seattle, Washington. These fish served as a baseline test group and were from Toutle Hatchery stock.

In the fall of 1977, eggs from the Toutle Hatchery were transported to the NWAFC hatchery and divided into two groups. The growth of fish in one group was accelerated using warm water (12-13°C) to produce 0-aged smolts by spring 1978. These experiments were described in the 1978-79 PNRC report, Appendixes D and E. Fish in the second group were reared under natural temperature conditions producing yearling smolts and are described in Appendixes B, E, and F of this report. The environmental conditions and measurements recorded during growth are presented in Appendix E.

Groups of yearling fish were transferred to seawater about every 2 weeks from May until September. Each group was divided into two populations and placed in separate net-pens. One population was repetitively subsampled for biochemical analyses (Appendix F); the second was used to monitor long-term adaptation and growth in seawater (Appendix B).

The baseline yearling fish were also used in an additional series of tests evaluating swimming performance of parr and smolts in fresh water and seawater using a Blazka-type respirometer (Appendix G).

DISCUSSION OF HATCHERY STUDIES

Smoltification Studies at the Hatcheries

Studies in 1978 on gill Na^{+}-K^{+} ATPase activities in several groups of salmon and steelhead from state and federal hatcheries in the Columbia River system were reported previously (Zaugg 1979). In 1979, the objective of the study remained the same: monitor changes in gill Na^{+}-K^{+} ATPase activity of selected groups of fish (Table 1) to evaluate their state of smoltification at release and to relate smoltification state to migration time from the hatchery to the estuary.

Freshwater gill Na^{+}-K^{+} ATPase activities were determined on 31 groups of coho and spring and fall chinook salmon and steelhead from state and federal hatcheries in the Columbia River system (Appendix A). Analyses began prior to hatchery release and continued beyond release whenever fish could be practically held over at the hatchery. Gill Na^{+}-K^{+} ATPase activities were also determined for out-migrant fish captured in the Columbia River estuary at Jones Beach, 76 km from the mouth of the river.

Coho salmon held in hatcheries beyond the normal smolting season (late April and May), as part of the size-time of release study conducted by state fishery agencies, experienced decreases in previously elevated gill Na^{+}-K^{+} ATPase activities, a loss of silvery coloration, and a reappearance of parr marks. This was observed in coho salmon at all four hatcheries. Data from Washougal coho salmon (Figure 3) are representative of the other test groups evaluated. Although fish released in June and July were in a parred stage, as judged by coloration and Na^{+}-K^{+} ATPase activities, migrants soon appeared at Jones Beach. All migrants tested at Jones Beach, however, had elevated Na^{+}-K^{+} ATPase activities, were beginning to lose parr marks, and were becoming more silvery. Gill Na^{+}-K^{+} ATPase activities increased with length of time from release, suggesting an active resmoltification. Thus, coho salmon which had undergone smoltification in hatchery ponds and reverted to parr in the hatchery, resmolted upon release in the first week of July. Fish then actually migrated more rapidly than those released in May in spite of lower river flow.

Likewise, some hatchery populations of fall chinook salmon, e.g., Kalama Falls and the March release from Spring Creek Hatchery, showed no physiological signs of smoltification in the hatchery (low gill Na^{+}-K^{+} ATPase activity and visible parr marks), yet after release into a river, a certain percentage of the population was capable of undergoing transformation to smolts and migrating rather quickly downstream. The

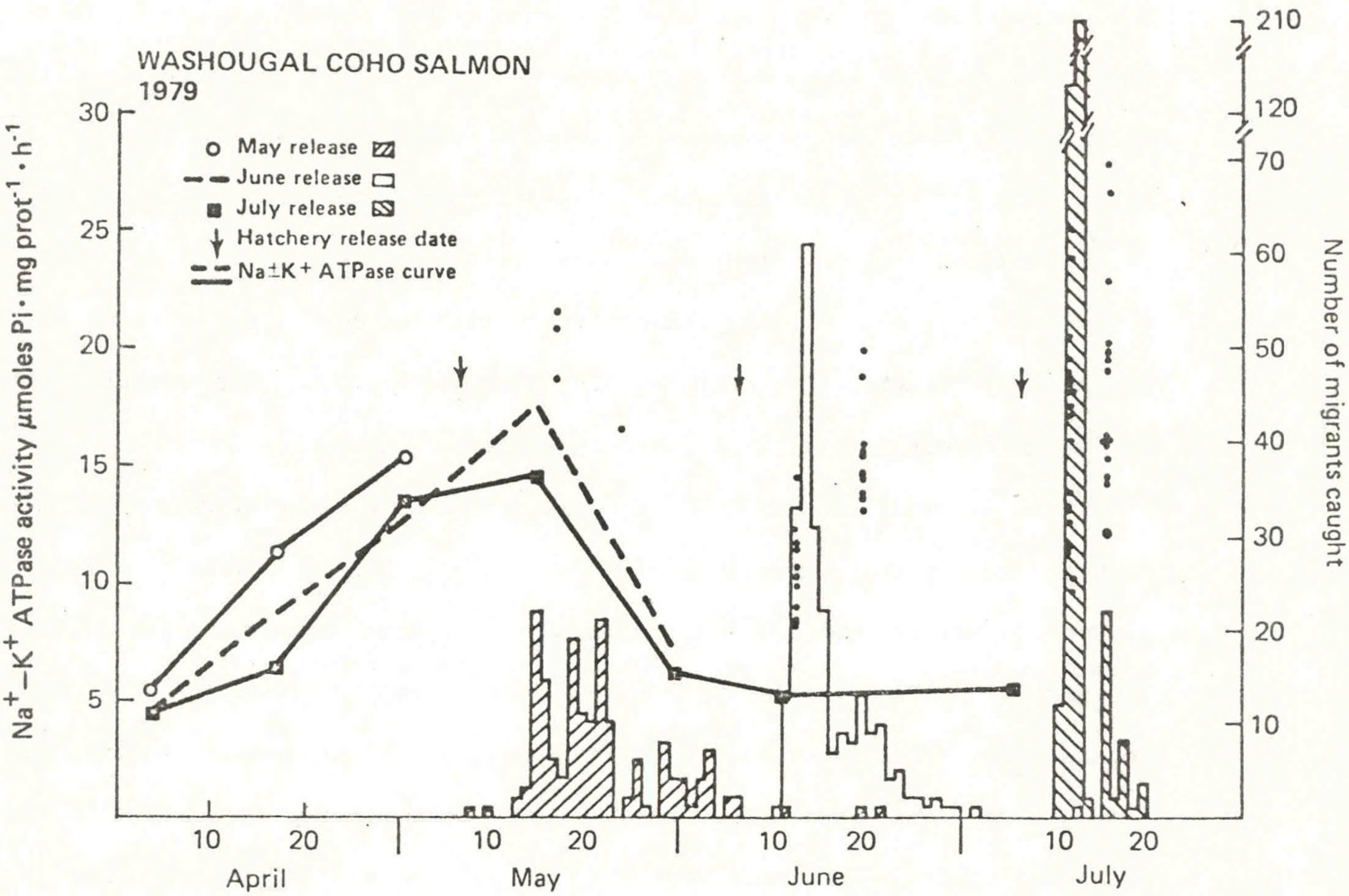


Figure 3.--Gill Na^{+}-K^{+} ATPase activities in Washougal coho salmon and numbers of migrants caught at Jones Beach. Arrows indicate releases on 7 May, 7 June, and 7 July. Single points (.) show gill Na^{+}-K^{+} ATPase activities for individual migrants caught at Jones Beach.

migrants showed elevated levels of gill Na^+-K^+ ATPase activity and silvery coloration typical of smolts at Jones Beach. Other fish of the same population not showing these characteristics probably remained in the river and delayed migration for several weeks. Fish released from the Kalama Falls Hatchery demonstrated this behavior, as did fish released in March from Spring Creek Hatchery. Generally, a higher percentage of fish in populations of fall chinook salmon with elevated gill Na^+-K^+ ATPase activities at the time of release migrate rapidly downstream than do fish in populations with low gill Na^+-K^+ ATPase activities, for example, the May release from Spring Creek Hatchery (Figures 4 and 5).

Fall chinook salmon held for delayed fall release migrated well in August from Spring Creek Hatchery when Na^+-K^+ ATPase levels were again rising (Figures 4 and 5); but migrated poorly from Bonneville and Willard Hatcheries from releases in October and November when Na^+-K^+ ATPase levels were declining (Figures 6 and 7). Both Bonneville and Willard groups were still being recovered at Jones Beach in April and May of the following spring. It seems probable that liberated fish which residualize and do not migrate to sea directly from streams may not imprint on home waters, but rather on waters in which they smolt and begin active seaward movement. If this is true then many surviving holdovers may not return to their hatchery of origin.

It is becoming increasingly evident that growth rate, water temperature, and other rearing conditions greatly influence the smoltification process in fall chinook salmon, and at the present time the relationships among these parameters are not well understood.

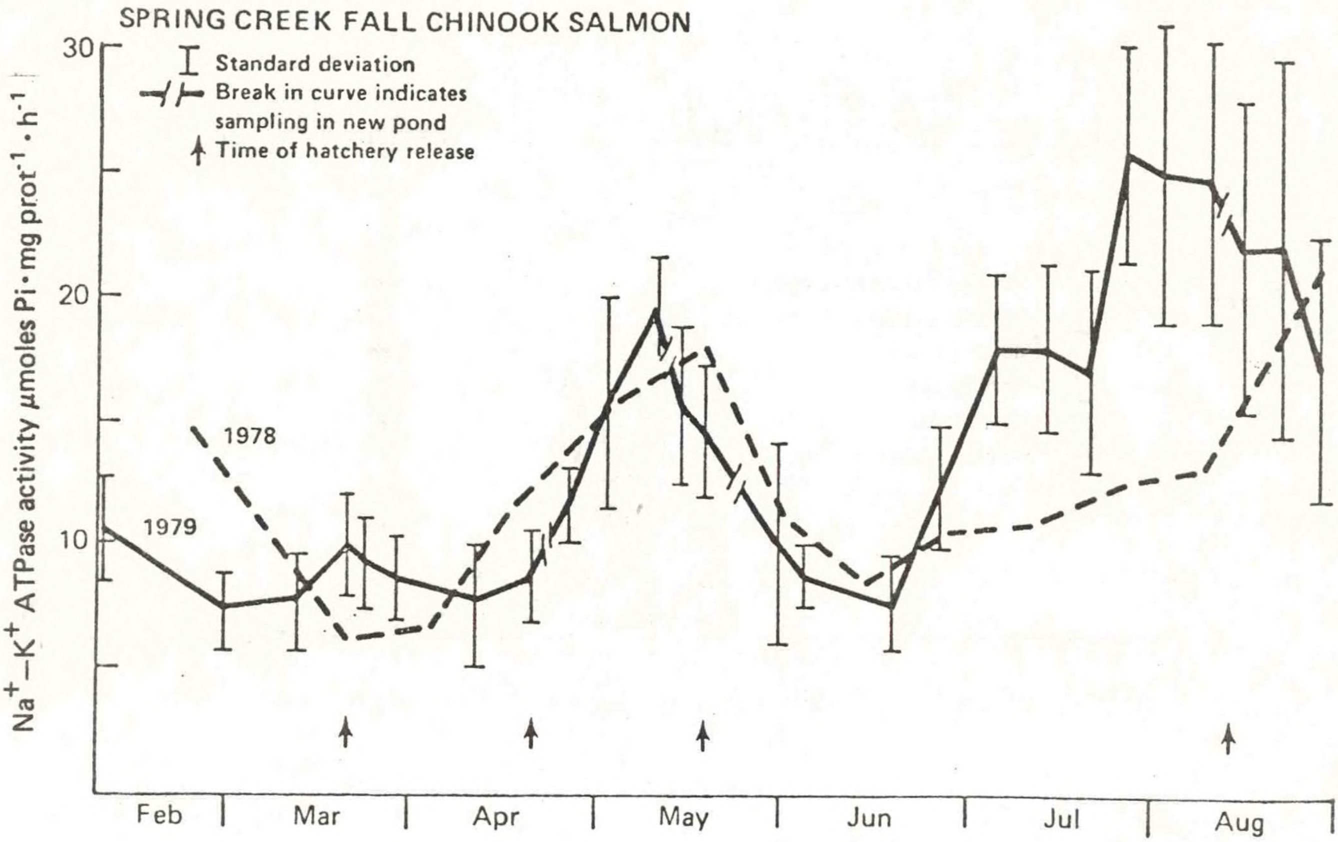


Figure 4.--Gill Na^+-K^+ ATPase activities in Spring Creek fall chinook salmon.

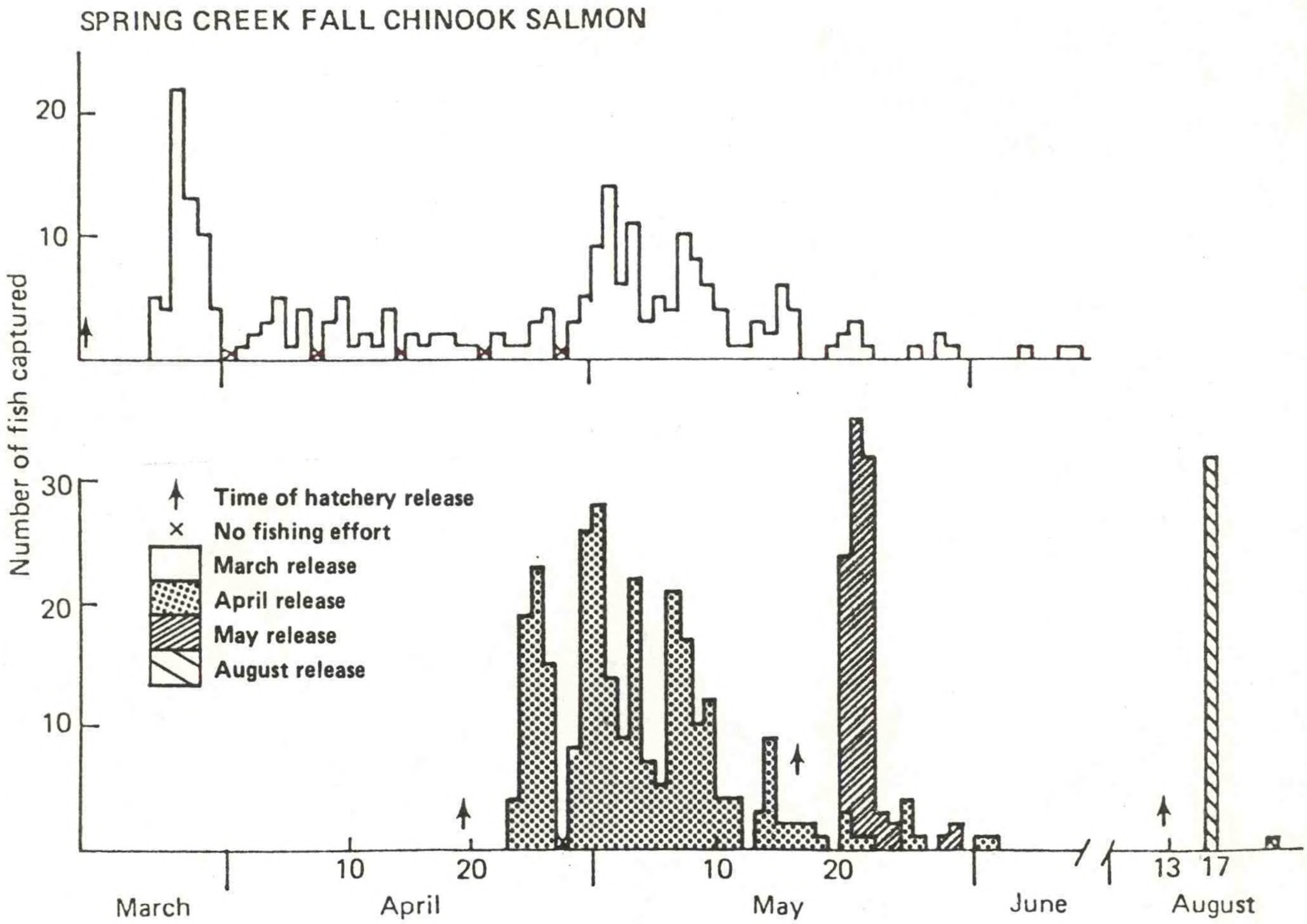


Figure 5.--Numbers of Spring Creek fall chinook salmon captured at Jones Beach.

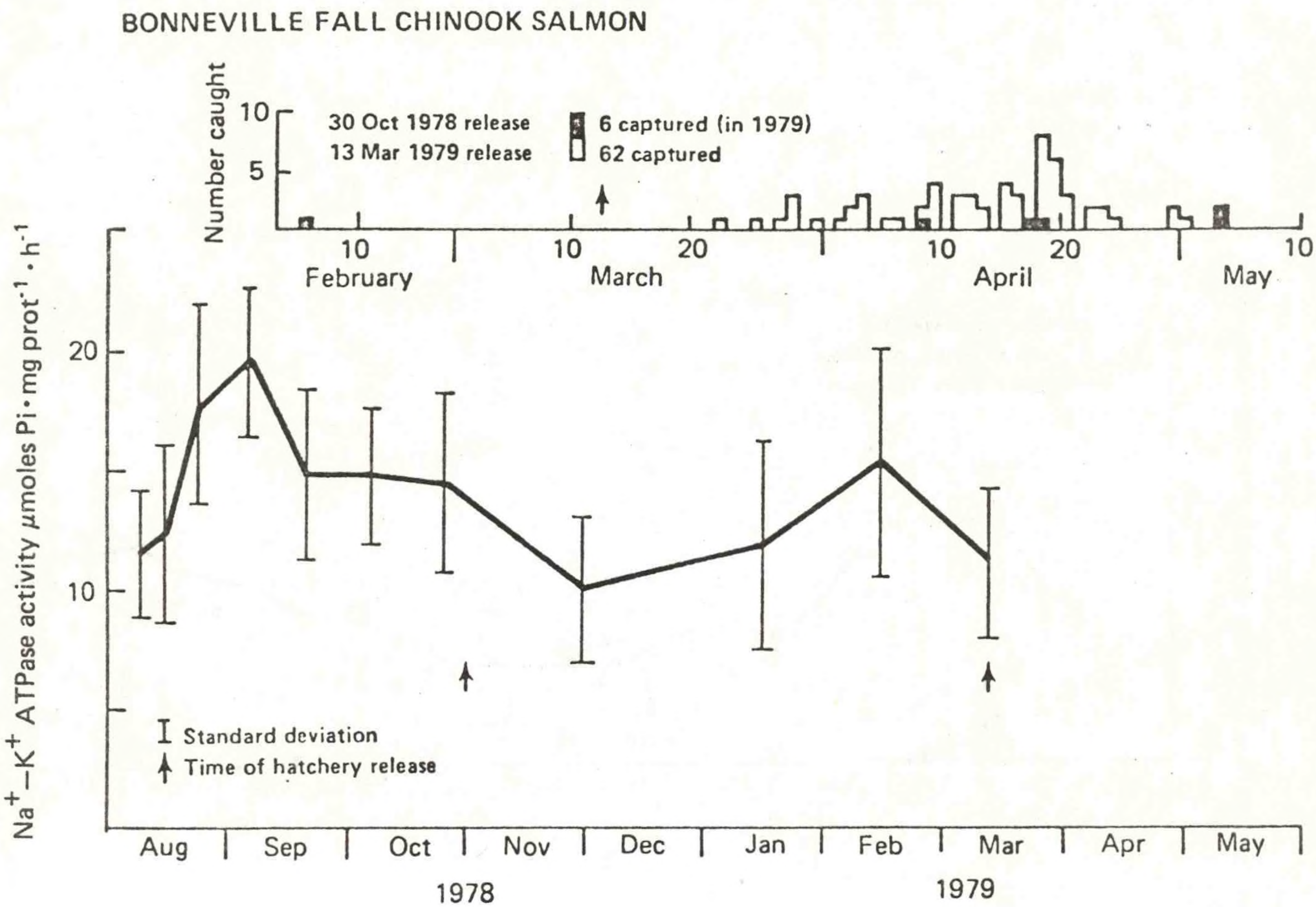


Figure 6.--Gill Na^{+}-K^{+} ATPase activities in Bonneville fall chinook salmon (Snake River stock) and numbers of migrants captured at Jones Beach.

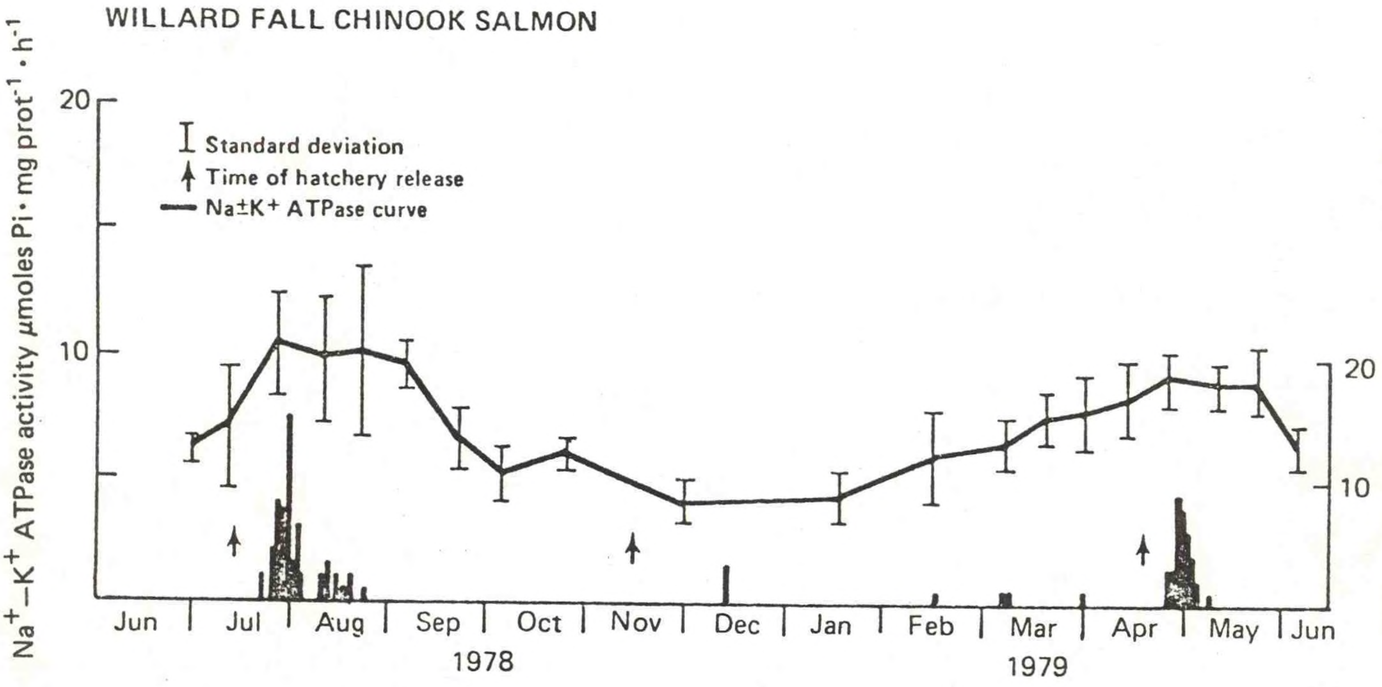


Figure 7.-- Gill Na^+-K^+ ATPase activities in Willard fall chinook salmon and numbers of migrants captured at Jones Beach.

Spring chinook salmon migrating from the Leavenworth Hatchery to Jones Beach had higher gill Na^{+}-K^{+} ATPase activities recorded at Jones Beach than fish of the same group transferred from the hatchery to Manchester and held in seawater (Figure 8). This observation suggests that the "sodium pump" activity in gills of fish which must migrate great distances downstream can be fully functional by the time seawater is reached, and that little physiological adjustment is needed for seawater acclimation.

Gill Na^{+}-K^{+} ATPase activities in steelhead reared at the Tucannon Hatchery were similar in 1978 and 1979 (Figure 9), showing a strong peak in early May accompanied by good development of silvery coloration. In contrast, steelhead reared at Chelan Hatchery (Figure 9), though much larger, failed to demonstrate high gill Na^{+}-K^{+} ATPase activity at the expected smolting time. The fish were dark and many were precocious males. The fact that water temperatures reached 13°C at the hatchery in late April and early May probably contributed to the minimal Na^{+}-K^{+} ATPase increase. Zaugg et al. (1972) observed that freshwater temperatures above 12°C inhibit Na^{+}-K^{+} ATPase activity in steelhead.

Fish Health Studies

The effect of husbandry techniques, disease, disease treatment, and environmental factors on fish health and smolt quality is substantial. Many chemotherapeutic compounds used in the treatment of parasitic and bacterial diseases of fish can affect the smolting process (Schmidt-Nielsen 1974; Lorz and McPherson 1976), and subclinical infections may be exacerbated with the stress of seawater entry. Chemotherapeutic compounds

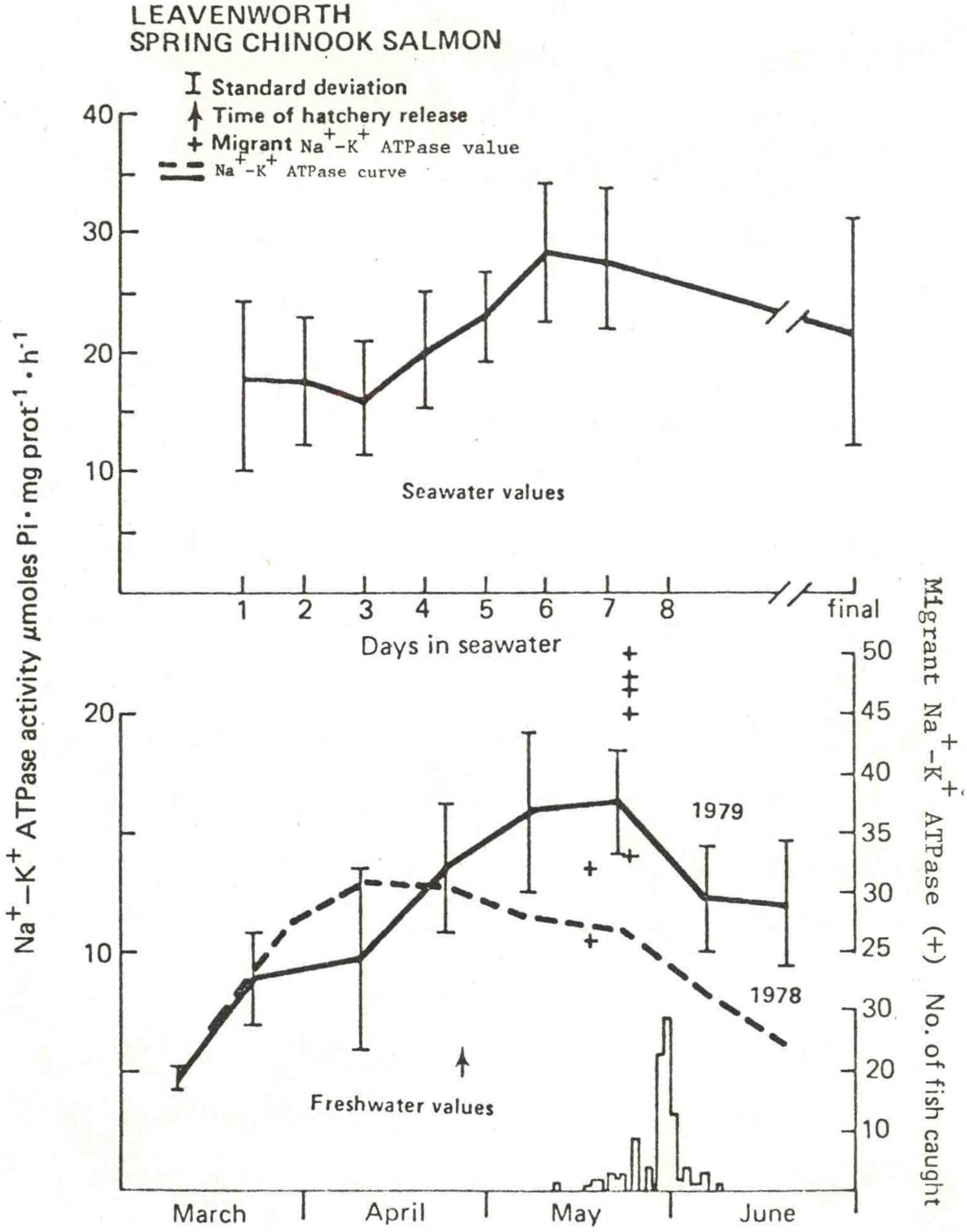


Figure 8.--Gill Na^+-K^+ ATPase activities in Leavenworth spring chinook salmon and numbers of migrants captured at Jones Beach. See Table 1 for date of seawater entry and termination.

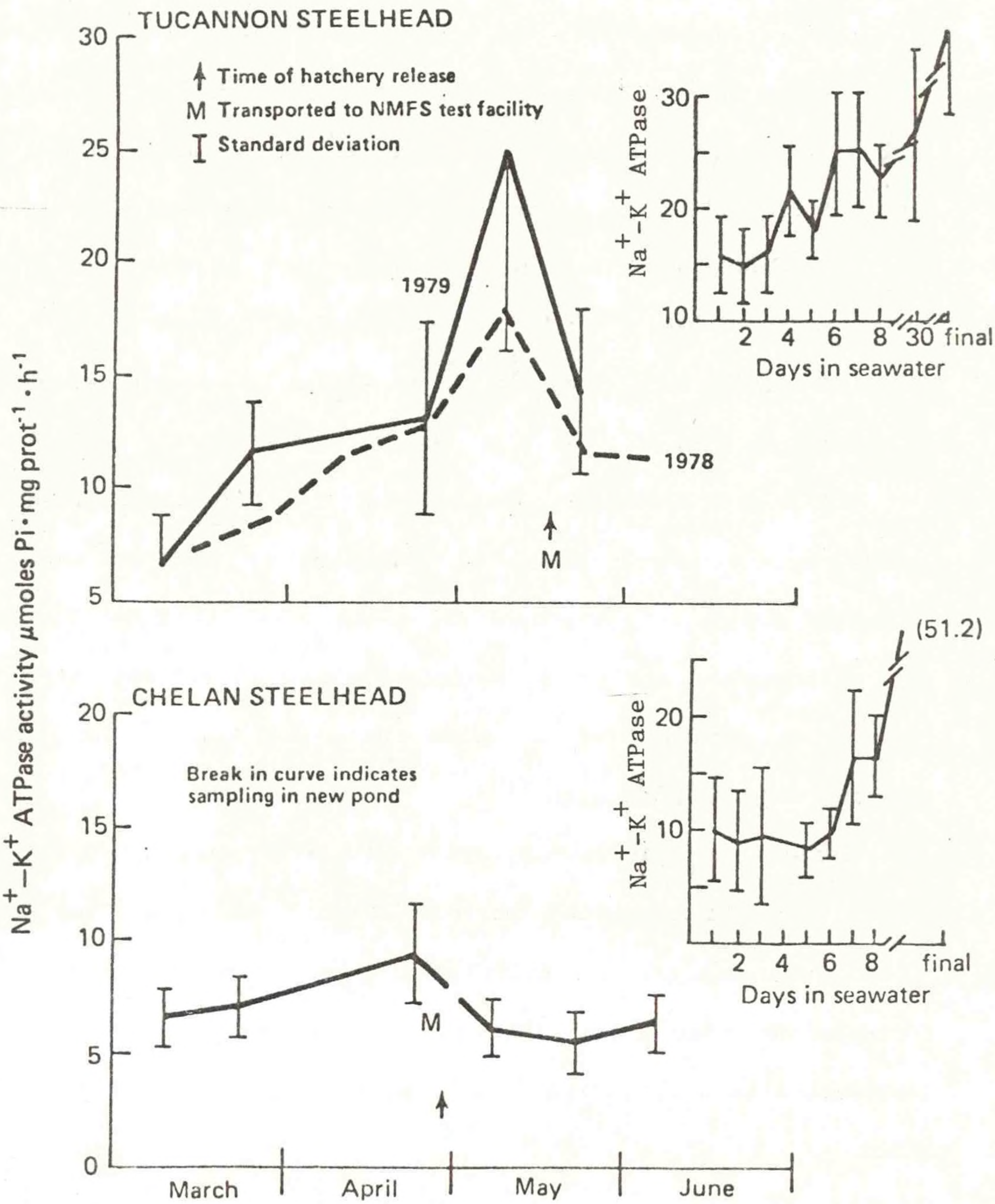


Figure 9.--Gill Na^{+}-K^{+} ATPase activities in Tucannon (top) and Chelan (bottom) steelhead in both fresh and seawater.

were used on many of the test groups in this study during various phases of freshwater rearing. For instance, Bonneville fall chinook salmon brought to Manchester in May 1979 had been treated with Formalin[a] and Malachite Green during the same month. Similarly, fall chinook salmon from Kalama Falls and Little White Salmon Hatcheries were treated with antibacterial drugs and disinfectants at or near the time of release. The poor seawater survival shown by these test groups could be, in part, due to the treatments received. In 1981, a cooperative study with the U.S. Fish and Wildlife Service will investigate the effect of chemotherapeutic compounds on smoltification.

BKD is a chronic pathological condition affecting salmonids in fresh water and may be the cause of mortality in fish at any time during saltwater residence (Novotny 1975; Ellis et al. 1978). The incidence of this pathogen was monitored, using a fluorescent antibody technique, in 39 test groups transported to seawater. All test groups analyzed were positive for BKD (Table 3).

Table 4 is a follow-up to the 1978 study showing final incidence of BKD in the test groups evaluated. In the case of Willard Hatchery fall chinook salmon, the intensity of the infection increased as the fish increased in size from 1978 to 1979, and any long term benefits from increased size of the fish at time of release may have been compromised by BKD.

[a] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 3.--1979 Summarized data for 60 fish subsamples collected for health surveys.

Hatchery	Species	Group no.	Date arrived Manchester	Hematocrit (% packed cell volume) N	Hematocrit X	Hematocrit SD	Hemoglobin (mg/dcl) N	Hemoglobin X	Hemoglobin SD	Percent of fish positive for BKD
Mont. Toutle	Coho	01	3-15-79	60	34.5	4.3	60	5.6	1.2	a/
" "	"	02	3-29-79	59	36.8	4.5	60	6.2	0.9	a/
" "	"	03	4-13-79	60	36.8	4.2	60	7.1	1.0	a/
" "	"	04	4-27-79	60	40.5	4.1	60	8.1	0.6	a/
" "	"	05	5-11-79	60	51.9	8.1	60	9.4	1.2	a/
" "	"	06	5-25-79	60	41.4	8.0	60	7.5	1.1	a/
" "	"	07	6-8-79	60	54.6	7.2	60	9.9	0.9	a/
" "	"	08	7-20-79	60	37.9	6.0	60	6.3	1.0	a/
" "	"	09	8-16-79	60	33.9	3.9	60	4.6	0.7	a/
" "	"	10	9-16-79	32	34.4	4.9	60	5.3	1.0	a/
Big Creek	"	01	5-7-79	60	35.3	4.8	60	6.8	1.1	a/
" "	"	02	6-7-79	N O T	S A M P L E D					
" "	"	03	7-6-79	55	48.9	5.2	59	7.8	1.1	1.7
Cascade	"	01	5-7-79	56	38.1	5.6	60	6.7	1.3	8.3
"	"	02	6-7-79	60	44.3	7.3	60	7.3	1.2	6.7
"	"	03	7-6-79	59	46.7	7.4	60	6.7	0.9	18.3
Toutle River	"	01	5-7-79	60	36.5	4.5	60	6.5	0.8	a/
" "	"	02	6-3-79	60	45.6	6.8	60	6.1	0.7	a/
" "	"	03	7-6-79	59	40.7	7.1	60	6.1	1.2	6.7
Washougal	"	01	5-7-79	51	35.9	8.0	60	7.4	1.4	a/
"	"	02	6-7-79	58	40.0	8.7	60	5.0	1.4	a/
"	"	03	7-6-79	60	44.1	9.1	60	6.6	1.3	8.3
Big White Salmon	Fa Ch	01	5-18-79	59	43.6	4.8	60	1.0	0.8	8.3
Bonneville	"	01	3-15-79	60	36.4	5.7	60	5.9	1.4	a/
"	"	02	5-20-79	60	46.1	5.1	60	6.5	0.8	23.3
Spring Creek	"	01	3-20-79	N O T	S A M P L E D		57	7.2	0.7	a/
" "	"	02	4-19-79	57	40.3	3.8	51	7.8	0.7	1.7
" "	"	03	5-18-79	59	40.4	9.6	59	7.9	0.7	a/
" "	"	04	8-10-79	60	43.4	4.5	60	7.0	0.7	a/
Willard	"	01	4-19-79	60	26.5	8.8	60	3.2	1.3	56.7
Elokomin	"	01	6-13-79	56	34.9	4.1	58	7.9	1.3	6.7
Washougal	"	01	6-13-79	60	42.5	4.5	60	6.9	0.8	5.0
Kalama Falls	"	01	7-16-79	56	41.7	3.7	60	5.6	0.7	11.7
Little White Salmon	"	01	6-22-79	48	35.4	3.4	60	5.5	1.1	3.3
Carson	Sp Ch	01	5-01-79	60	36.7	10.1	60	5.2	1.8	33.3
Leavenworth	"	01	4-25-79	58	46.3	9.8	58	6.5	1.6	21.7
Chelan	Stld	01	4-25-79	60	49.8	7.7	60	8.9	1.6	1.7
Wells	"	01	5-10-79	58	50.8	6.9	60	9.6	1.1	3.3
Tucannon	"	01	5-14-79	60	53.0	7.7	60	9.2	1.3	1.7

a/ No assay.

Table 4.--Follow-up data to 1979 PNRC Report Appendix C giving final morbidity levels of covert BKD infections in 1978 test fish at time of seawater entry.

Hatchery	Specie	% BKD infection
Willard I	Coho	15.0
Willard II	"	16.7
Willard III	"	40.7
Kalama	"	85.0
Big Creek/Cowlitz	"	31.6
Big Creek/Big Creek	"	6.7
Carson	"	5.0
Sandy	"	30.0
Klickitat	"	3.3
Toutle	"	46.7
Bonneville I	Fall Chinook	10.1
Bonneville II	"	5.0
Willard I	"	41.7
Willard II	"	36.6
Spring Creek	"	0
Cowlitz	"	93.3
Little White Salmon	"	11.6
Kalama I	"	11.6
Kalama II	"	3.3
Toutle	"	6.7
Kooskia	Spring Chinook	90.0
Leavenworth	"	0
Kalama	"	0
Carson	"	50.8
Chelan	Steelhead	86.7
Tucannon	"	21.7
Wells	"	83.3
Dworshak	"	16.7
Skamania	"	63.3

Abnormally low or high hematocrit and hemoglobin values can be due to a number of factors including dietary anemias, infectious disease, stage of gonad development, environmental stress, dehydration, or anoxia. Examination of the test groups in Table 3 shows that few of the mean values for hematocrit or hemoglobin were above or below values considered normal, with one exception, the yearling fall chinook salmon from Willard Hatchery. This was the most anemic population of fish encountered thus far, with a mean hematocrit value of 26.5% and a hemoglobin value of 3.2 milligrams per dekaliter of blood. This condition also coincides with a 56.7% BKD infection rate, which is probably the cause of the anemia.

Cause of mortality after transfer to seawater is summarized in Table 5. The principal cause of mortality among test groups was osmoregulatory dysfunction or vibriosis. Few other pathogens were isolated from moribund fish. If more fish had survived in seawater for an extended period of time, it is probable that BKD would have been isolated more freqently from moribund fish.

Seawater Adaptation Studies

A second phase of the overall study was to evaluate the seawater adaptation of fish. At or near the time of hatchery release,groups of fish from many of the cooperating hatcheries were transferred to seawater net-pens near Manchester, Washington (Figure 2). The test groups were monitored for growth, mortality, disease, reversion to parr, and various physiological changes. Performance results are summarized in Table 6. Specific details of the study are contained in Appendixes B and F.

Serially released (May, June, July) coho salmon were evaluated from each of four hatcheries (Toutle, Washougal, Big Creek, and Cascade). There was a direct relationship between time of seawater entry, survival, and

Table 5.-- Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Coho											
Big Creek Group 1	200	112	56.0	88	81	7	3.5	61	30.5	20	10.0
Big Creek Group 2	200	64	32.0	136	41	95	47.5	26	13.0	15	7.5
Big Creek Group 3	200	77	38.5	123	119	4	1.3	92	30.7	27	9.0
Cascade Group 1	200	82	41.0	118	106	12	6.0	91	45.5	15	7.5
Cascade Group 2	200	104	52.0	96	95	1	0.5	75	37.5	20	10.0
Cascade Group 3	200	70	35.0	130	123	7	3.5	100	33.3	23	7.7
Toutle Group 1	200	92	46.0	108	110	2 a/	1.0	89	44.5	21	10.5
Toutle Group 2	200	72	36.0	128	121	7	3.5	94	47.0	27	13.5
Toutle Group 3	200	68	34.0	132	126	6	3.0	107	53.5	19	9.5
Washougal Group 1	200	66	33.0	134	126	8	4.0	98	49.0	28	14.0
Washougal Group 2	200	77	38.5	123	116	7	3.5	97	48.5	19	9.5
Washougal Group 3	200	64	32.0	136	131	5	2.5	104	52.0	27	13.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD b/	775 c/	1669 c/	7244 c/	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM d/	Aero e/ Liq	Osmo f/ Dys	Furun g/	Other
Coho															
Big Creek Group 1	6	0	11	1	0	0	0	0	0	2	0	0	0	0	0
Big Creek Group 2	3	1	9	2	0	0	0	0	0	0	0	0	0	0	0
Big Creek Group 3	7	0	13	6	0	0	0	0	1	0	0	0	0	0	0
Cascade Group 1	6	2	2	4	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 2	10	1	5	3	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 3	10	0	11	2	0	0	0	0	0	0	0	0	0	0	0
Toutle Group 1	12	0	5	3	0	0	0	0	0	1	0	0	0	0	0
Toutle Group 2	8	1	8	6	0	0	0	1	0	3	0	0	0	0	0
Toutle Group 3	12	0	6	1	0	0	0	0	0	0	0	0	0	0	0
Washougal Group 1	13	1	7	5	0	0	0	0	0	1	0	0	0	0	1
Washougal Group 2	8	1	9	0	0	0	0	0	0	0	0	0	0	0	1
Washougal Group 3	11	0	9	7	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 5.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Baseline <u>Coho</u> <u>(Toutle Stock)</u>											
Serial Entry 1	150	47	31.3	103	103	0	0.0	88	58.7	15	10.0
Serial Entry 2	150	33	22.0	117	116	1	0.7	90	60.0	26	17.3
Serial Entry 3	151	51	33.8	100	98	2	1.3	76	50.7	22	14.7
Serial Entry 4	150	56	37.3	94	97	3[a]	2.0	77	51.3	20	13.3
Serial Entry 5	149	62	41.6	88	84	4	2.7	65	43.6	19	12.8
Serial Entry 6	150	57	38.0	93	88	5	3.3	66	44.0	22	14.7
Serial Entry 7	150	63	42.0	87	75	12	8.0	61	40.7	14	9.3
Serial Entry 8	150	85	56.7	65	72	7[a]	4.7	54	36.0	18	12.0
Serial Entry 9	150	86	57.3	64	61	3	2.0	50	33.3	11	7.3
Serial Entry 10	150	139	92.7	11	8	3	2.0	7	4.7	1	0.7

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD[b]	775[c]	1669[c]	7244[c]	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM[d]	Aero Liq[e]	Osmo Dys[f]	Furun[g]	Other
Baseline <u>Coho</u> <u>(Toutle Stock)</u>															
Serial Entry 1	10	1	3	0	1	0	0	0	0	0	0	0	0	0	0
Serial Entry 2	23	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 3	15	0	3	2	1	0	0	0	0	0	0	0	0	1	0
Serial Entry 4	12	1	5	2	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 5	7	0	9	2	0	0	0	0	0	1	0	0	0	0	0
Serial Entry 6	12	0	3	7	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 7	8	0	3	3	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 8	5	0	7	3	2	0	0	0	0	0	0	0	0	0	1
Serial Entry 9	4	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 5.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Spring Chinook											
Carson	200	41	20.5	159	150	9	4.5	144	7.2	6	3.0
Leavenworth	200	74	37.0	126	133	7[a]	3.5	122	61.0	11	5.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD[b]	775[c]	1669[c]	7244[c]	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM[d]	Aero[e] Liq	Osmo[f] Dys	Furun[g]	Other
Spring Chinook															
Carson	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Leavenworth	6	0	3	1	0	0	0	0	0	1	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 5.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Fall Chinook											
Willard Group 1	300	62	20.7	238	205	33	11.0	91	30.3	114	38.0
Willard Group 2	300	49	16.3	251	202	49	16.3	108	36.0	94	31.3
Bonneville (late yearling)	300	168	56.0	132	80	52	17.3	46	15.3	34	11.3
Spring Creek Group 1	303	67	22.1	236	200	36	11.9	83	27.4	117	38.6
Spring Creek Group 2	300	12	4.0	288	276	12	4.0	241	80.3	35	11.7
Willard Group 3	150	43	28.7	107	108	1[a]	0.7	75	50.0	33	22.0
Big White Salmon	150	11	7.3	139	130	9	6.0	116	77.3	14	9.3
Spring Creek Group 3	300	7	2.3	293	275	18	6.0	200	66.7	75	25.0
Bonneville (tules-78 brood)	300	12	4.0	288	181	107	35.7	133	44.3	48	16.0
Elokomin	300	36	12.0	264	210	54	18.0	194	64.7	16	5.3
Little White Salmon	301	37	12.3	263	237	26	8.7	148	49.3	89	29.7
Washougal	300	48	16.0	252	176	76	25.3	122	40.7	54	18.0
Toutle	133	17	12.8	116	99	17	12.8	93	69.9	6	4.5
Kalama Falls	300	41	13.7	259	238	21	7.0	87	29.0	151	50.3
Spring Creek Group 4	300	232	77.3	68	64	4	1.3	54	18.0	10	3.3

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD[b]	775[c]	1669[c]	7244[c]	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM[d]	Aero[e] Liq	Osmo[f] Dys	Furun[g]	Other
Fall Chinook															
Willard Group 1	3	0	0	0	1	0	0	0	0	0	0	0	110	0	0
Willard Group 2	4	1	3	1	0	0	0	0	0	1	0	0	84	0	0
Bonneville (late yearling)	3	2	1	0	0	0	0	0	0	0	0	0	28	0	0
Spring Creek Group 1	6	0	6	3	0	0	0	0	0	0	0	0	102	0	0
Spring Creek Group 2	9	0	21	4	0	1	0	0	0	0	0	0	0	0	0
Willard Group 3	0	0	0	0	0	0	0	0	0	1	0	0	32	0	0
Big White Salmon	1	0	10	2	0	0	0	0	0	0	0	0	0	0	1
Spring Creek Group 3	8	0	14	2	0	0	0	0	0	0	0	0	51	0	0
Bonneville (tules-78 brood)	4	0	7	0	0	0	0	0	0	0	0	0	37	0	0
Elokomin	3	0	6	7	0	0	0	0	0	0	0	0	0	0	0
Little White Salmon	2	0	11	4	0	0	0	0	0	0	0	0	72	0	0
Washougal	0	0	3	1	0	0	0	0	0	0	0	0	50	0	0
Toutle	1	0	4	1	0	0	0	0	0	0	0	0	0	0	0
Kalama Falls	1	0	10	1	0	0	0	0	0	0	0	0	139	0	0
Spring Creek Group 4	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 5.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Steelhead											
Chelan (Leavenworth)	200	16	8.0	184	156	28	14.0	67	33.5	89	44.5
Wells (Winthrop)	200	9	4.5	191	186	5	2.5	32	16.0	154	77.0
Tucannon	200	37	18.5	163	111	52	26.0	51	25.5	60	30.0

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test Group	Nega-tive	BKD b/	775 c/	1669 c/	7244 c/	775/ 1669	775/ 7244	1669/ 7244	1699/ BKD	775/ BKD	ERM d/	Aero e/ liq	Osmo f/ dys	Furun g/	Other
Steelhead															
Chelan (Leavenworth)	3	0	20	4	4	0	3	0	0	0	0	0	55	0	0
Wells (Winthrop)	0	0	3	1	1	0	2	0	1	0	0	0	145	0	1
Tucannon	6	0	10	0	0	0	6	0	0	0	1	0	37	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 6.--Summary of seawater performance of chinook and coho salmon and steelhead.

Parameter	Fish: Coho	Steelhead	Spring chinook	Fall chinook
Initial loss due to osmoregulatory stress	Low: Coho that are unready for long-term adaptation to seawater can generally survive for 30 days or more.	Potentially high: Fish size doesn't seem as important as physiological status. Possibly exacerbated by latent freshwater pathogenic organisms and ambient freshwater and seawater temperatures.	Potentially high (>30%): Smaller fish may die due to osmoregulatory dysfunction if there are no peaks in physiological profiles prior to transfer to seawater.	Potentially high: Fish weighing less than 5 g (spring to mid-summer) or 10 g (after mid-summer) may die due to osmoregulatory dysfunction if there are no peaks in physiological profiles prior to introduction to seawater.
Reversion to nonsmolted condition	Likely to occur in substantial proportions (>40%) if there are no peaks in physiological profiles immediately prior to seawater transfer.	Likely to occur in substantial proportions among smaller fish if there are no peaks in physiological profiles immediately prior to seawater transfer. It seems that freshwater and seawater temperatures in excess of 12°C can inhibit some physiological smoltification processes and therefore may influence percent reversion to a nonsmolted condition.	Two patterns have been observed: 1) reversions seldom occur in test groups introduced to seawater in the spring to mid-summer because potentially susceptible--i.e., small-fish die due to osmoregulatory problem and 2) the smaller fish in test groups introduced to seawater after mid-summer can show long-term retention of parr and transitional characteristics.	Low: Small fish die due to osmoregulatory stress, however, some reversions occur, with the incidence of reversions higher in test groups entering seawater after mid-summer.
Growth	Directly related to the parr/smolt ratio: An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Directly related to the parr/smolt ratio: An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Good: Most of the slower growing--i.e., small--fish have been eliminated from the test groups by osmoregulatory dysfunction; however, in groups entering seawater after mid-summer the growth can be related to the parr/smolt ratio. An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Fair: Some of the slow growing--i.e., small--fish eliminated by osmoregulatory dysfunction; therefore, the growth can be related to the parr/smolt ratio. An increase in the percent of parred fish will result in corresponding decrease in the mean growth rate of the test group.
Resistance to vibriosis (determined by unvaccinated/vaccinated ratio)	Good: Losses start occurring after 50 days with most losses occurring after 120 days of seawater residence.	Fair: Losses start occurring approximately 10 days after transfer to seawater. The ability to provide immune defense against vibriosis may be related to the degree of infection by overt and latent freshwater pathogenic organisms.	Fair: Losses start approximately 15 days after transfer to seawater.	Fair: Losses start approximately 15 days after transfer to seawater.
Total mortality	Nonsmolts die from 5 to 9 months after seawater entry; therefore, total mortality depends on percent parr and severity of *Vibrio* outbreaks. Freshwater disease history also is important in determining overall seawater survival.	Long term osmoregulatory mortalities occur concurrent with losses due to vibriosis.	Total mortality may be substantial, with the initial losses due to osmoregulatory dysfunction followed by losses due to vibriosis.	Total mortality may be substantial, with the initial losses due to osmoregulatory dysfunction followed by losses due to vibriosis.
Precocious males	Low incidence but when present, precocious males are the larger fish in the population at seawater entry.	Low incidence.	Precocious males may comprise up to 8% of the fish in the test group. Precocious males usually are the larger fish in the population at seawater entry.	Low incidence.

fish size at time of seawater entry, i.e., the fish released in May were better adapted to seawater than fish of about the same size released in June and July (Appendix B). Also, the mortality rate (entire population) generally increased with each successive entry period.

Fifteen entries of fall chinook from nine hatcheries were evaluated for seawater adaptability. In general, the larger (mean size) test groups at seawater entry had the highest survival. However, this was dependent on the freshwater disease history, rearing environment, and status of smoltification. Mortality related to osmoregulatory dysfunction in fall chinook salmon usually occurs within the first 10-15 days after seawater entry. Based on the data collected during this year and over the past several years, it appears that a 30-day holding period is sufficient to evaluate fall chinook salmon seawater adaptation.

The two spring chinook salmon entries studied showed a relatively high incidence of precocious males. These early maturing fish were initially the largest in the test groups but died after several months in seawater. Vibriosis was the major cause of mortality in spring chinook salmon.

Steelhead test groups were affected by osmoregulatory problems throughout the study. Despite an apparent high percentage of smolts, overall seawater survival was poor. The poor survival may have been a result of high water temperature. Studies have shown that freshwater rearing temperatures above 12°C affect behavior and represses ATPase activity of steelhead (Zaugg et al. 1972). A test was conducted to observe the effects of seawater temperature on survival, changes in the parr-smolt ratio, and incidence of external darkening of steelhead (Appendix C). Comparisons were made between fish reared in circular tanks supplied with chilled running (8.0°-12.0°C) or near-ambient (10.0°-16.5°C) seawater and fish held in seawater net-pens in Clam Bay at 9.3°-15.3°C (ambient). Results showed an inverse relationship between survival and seawater rearing temperature. Also, there were generally higher proportions of parred and transitional fish in the near-ambient tanks than in the chilled tanks or net-pens. The incidence of external darkening was highest in the tanks with water supplied at ambient temperatures until the end of the study when water failures stressed the fish.

Changes in physiological parameters (gill Na^+-K^+ ATPase, plasma thyroid hormones, and blood ions) occurred during smoltification and seawater adaptation in coho salmon, fall and spring chinook salmon, and steelhead. The physiological profiles of gill Na^+-K^+ ATPase and plasma thyroid hormones during smoltification in freshwater and seawater adaptation were similar to those reported in the 1978-79 PNRC Report except for steelhead. Monovalent plasma electrolytes monitoring showed that changes during smoltification and seawater adaptation were similar to those previously reported; that is, no significant changes were observed in freshwater Na^+, K^+, or Cl^- values.

Divalent plasma electrolytes were also monitored in both fresh water and seawater. During the freshwater sampling period, plasma Ca^{++} levels were found to fluctuate in opposition to plasma T_4 concentration in the coho and spring chinook salmon, but not in the steelhead. This suggests, for the genus <u>Oncorhynchus</u>, that an antagonistic relationship between T_4 and prolactin similar to that found in amphibians may exist and yet a different mechanism may be active in <u>Salmo</u>. Plasma Ca^{++} levels remained relatively constant at seawater entry. Plasma Mg^{++} concentrations showed little change in freshwater; however, at seawater entry the plasma concentrations changed in a pattern similar to that observed for Na^+ and Cl^-.

A statistically significant relationship was found between the area under the T_4 curves in fresh water and the number of surviving smolts at termination of the study in coho salmon (Figure 10). A similar relationship was suggested for spring chinook salmon but not for steelhead; however, insufficient data precluded statistical analysis. No T_4 data were obtained on fall chinook salmon because of their small size at time of sampling.

At present, we have no explanation for the generally poor seawater survival of steelhead compared to coho and spring chinook salmon. It appears from our preliminary findings that the underlying physiological mechanisms controlling seawater adaptation and survival of steelhead are fundamentally different from those of coho and chinook salmon, and, therefore, require additional study. Due to the observations of the relationships between plasma thyroid hormone profiles in fresh water with surviving smolts in seawater, we continue to support the use of these measurements to predict the optimal time of seawater transfer for coho and chinook salmon.

DISCUSSION OF BASELINE STUDIES

Smoltification Studies at the Hatchery

In 1979, 10 groups of baseline yearling coho salmon (Toutle stock), reared at the NMFS Seattle Laboratory, were evaluated. Fish were serially transferred to seawater from May to September 1979. Freshwater smoltification indices peaked at about the fifth entry (early May), remained relatively constant through June, and then declined in the late entry groups.

Gill Na^+-K^+ ATPase activities and plasma T_4 concentrations were dramatically higher in yearling fish than 0-age fish during smoltification in fresh water (Figures 11 and 12). Although no strong peak was observed

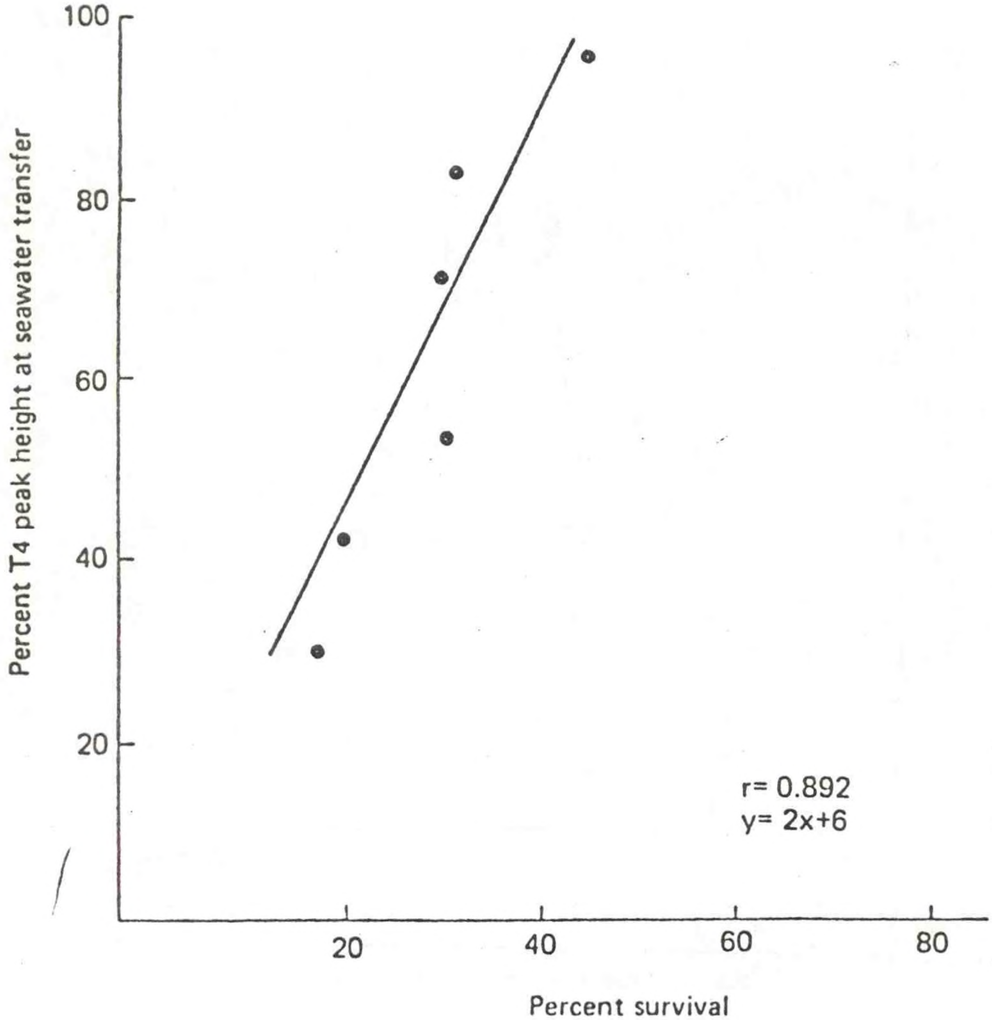


Figure 10.--Regression analysis of the relationship between plasma T_4 concentrations and percent surviving smolts in yearling coho salmon.

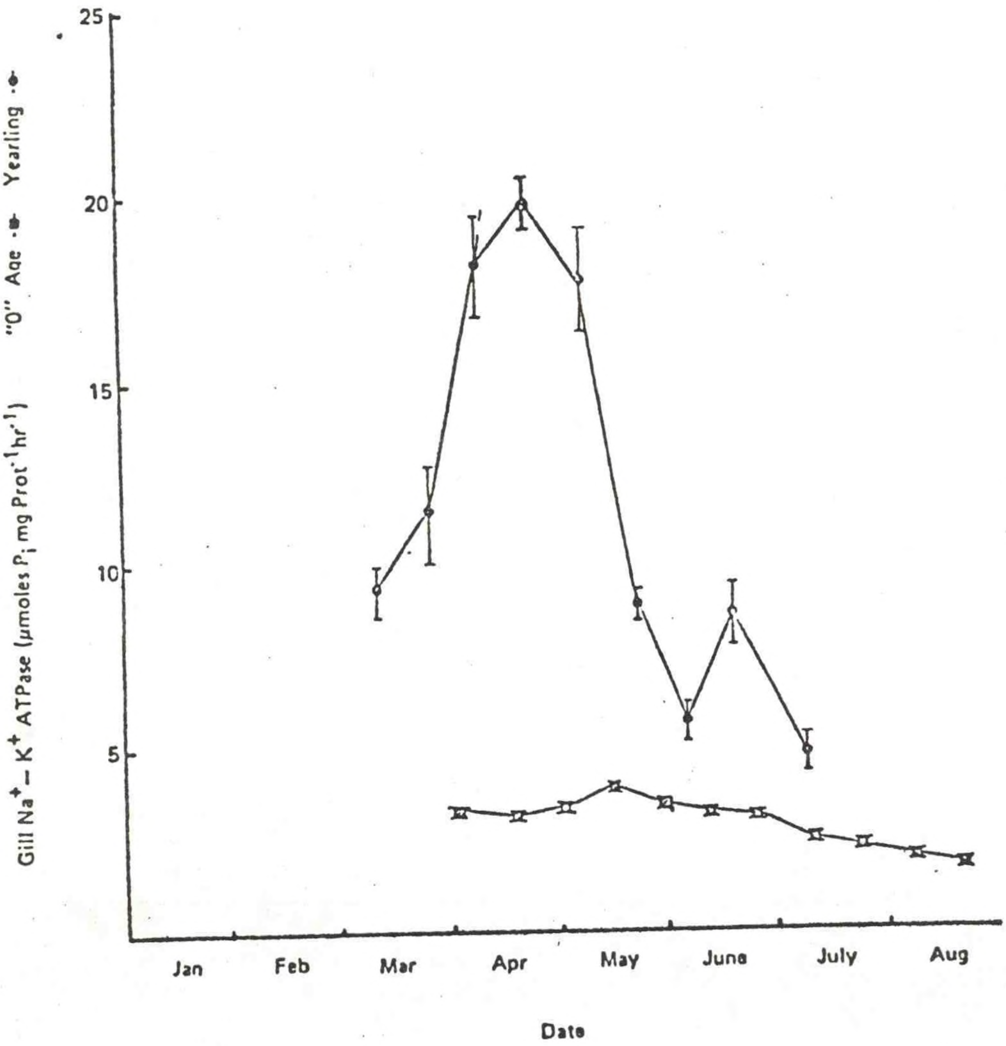


Figure 11.--Gill Na^{+}-K^{+} ATPase activities vs time for 0-age and yearling baseline coho salmon during smoltification in fresh water.

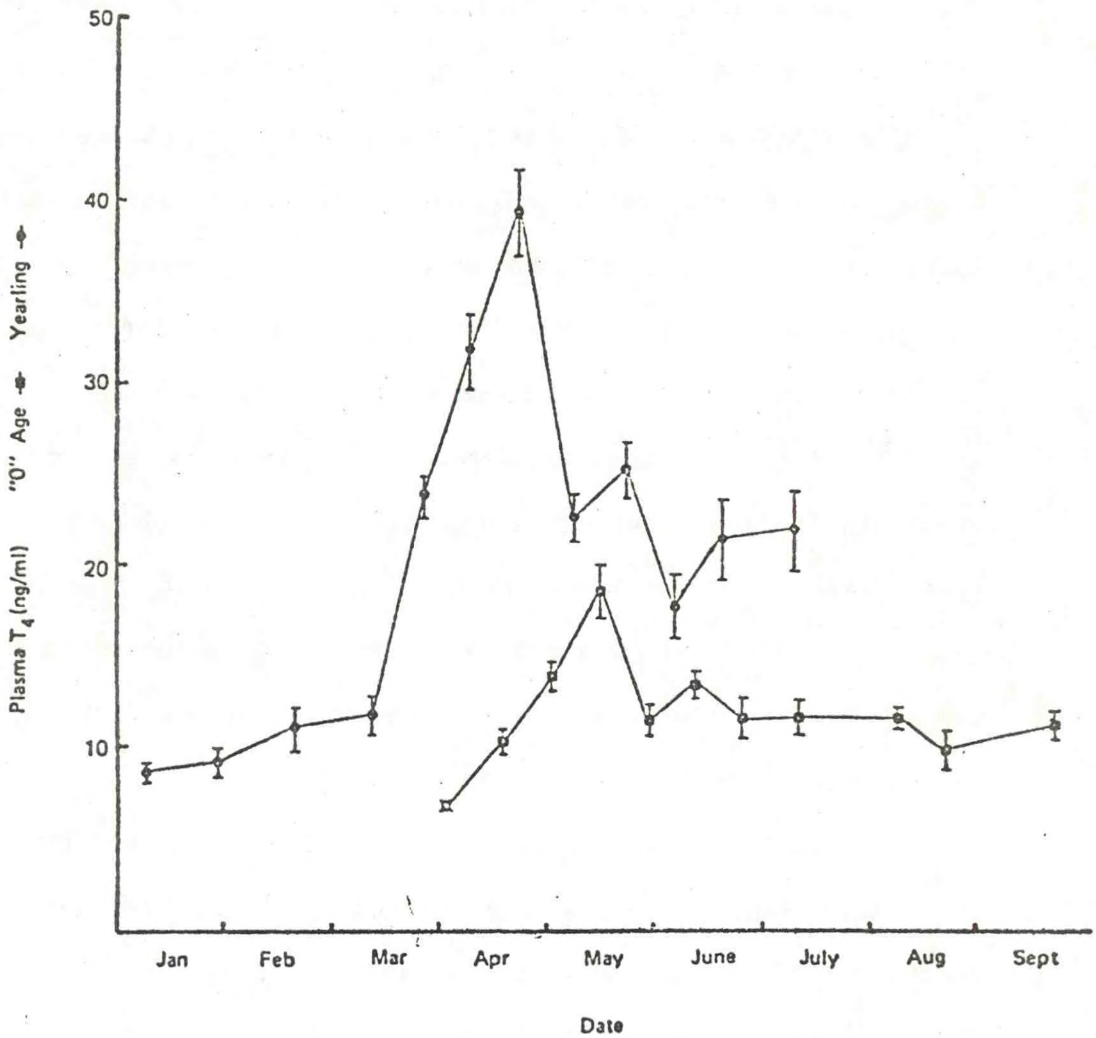


Figure 12.--Plasma T_4 concentrations vs time for 0-age and yearling baseline coho salmon during smoltification in fresh water.

in gill Na^+-K^+ ATPase for the 0-age fish in fresh water, the enzyme activity patterns for both 0-age and yearling baseline fish were similar in seawater (Appendix F). Changes in the plasma thyroid hormones at seawater entry were variable and complex for both the 0-age and yearling coho salmon.

Measurements of plasma electrolytes were made only on the yearling fish. No statistically significant changes were observed for Na^+ or Cl^-; whereas, K^+, Ca^{++}, and Mg^{++} showed short transitory increases during the period of freshwater measurements. The changes observed for the monovalent electrolytes in the yearling fish were similar to those reported last year for yearling coho salmon. The divalent electrolyte (Ca^{++}) concentration was relatively constant at seawater entry while plasma Mg^{++} concentrations followed a pattern similar to Na^+ and Cl^-.

In 1978, a study to determine changes in swimming performance, critical fatigue levels, and metabolic rates during the parr-smolt transformation of coho salmon was conducted with baseline coho salmon (Flagg and Smith 1979). A follow-up study was conducted in 1979 to monitor the effect of seawater entry on swimming performance of yearling baseline coho salmon (Appendix G).

Results indicate that in most cases direct seawater transfer will have an initial debilitating effect on coho salmon. There were no immediate deaths attributed to swimming fatigue in either fresh water or seawater. However, delayed mortalities did occur following seawater swimming stamina tests. Results suggest a 7-day minimum holding period after subjecting coho salmon to a stress to determine delayed mortality. There were no significant correlations between the ability to survive freshwater swimming fatigue and swimming stamina levels, 90 day seawater survival, or mean length or mean water temperature. At seawater entry, survival following seawater swimming fatigue stress was significantly related to base freshwater gill Na^+-K^+ ATPase activity ($\alpha = 0.02$) and freshwater plasma thyroxine (T_4) concentrations ($\alpha = 0.01$). The findings suggest that this type of test can be used effectively in determining the status of smoltification and seawater survival of coho salmon. Swimming fatigue survival progressively increased as entry groups approached the peak of smoltification [judged by external characteristics, plasma thyroxine (T_4), and gill Na^+-K^+ ATPase levels], then declined thereafter.

Fish Health Studies

The principal cause of mortality among test groups was vibriosis (Table 5). Few other pathogens were isolated from moribund fish.

Seawater Adaptation Studies

Comparisons were made of all of the measured physiological parameters with percentages of surviving and smolted fish at the termination of the study. The percentages of surviving and smolted fish at the termination of the study were greater in the yearling baseline coho salmon than in the 0-age fish. Statistically significant positive relationships were found between the area under the freshwater plasma T_4 curve and surviving smolts in yearlings and between the area under the freshwater plasma T_3 curve and surviving smolts in the 0-age fish (Figures 13 and 14).

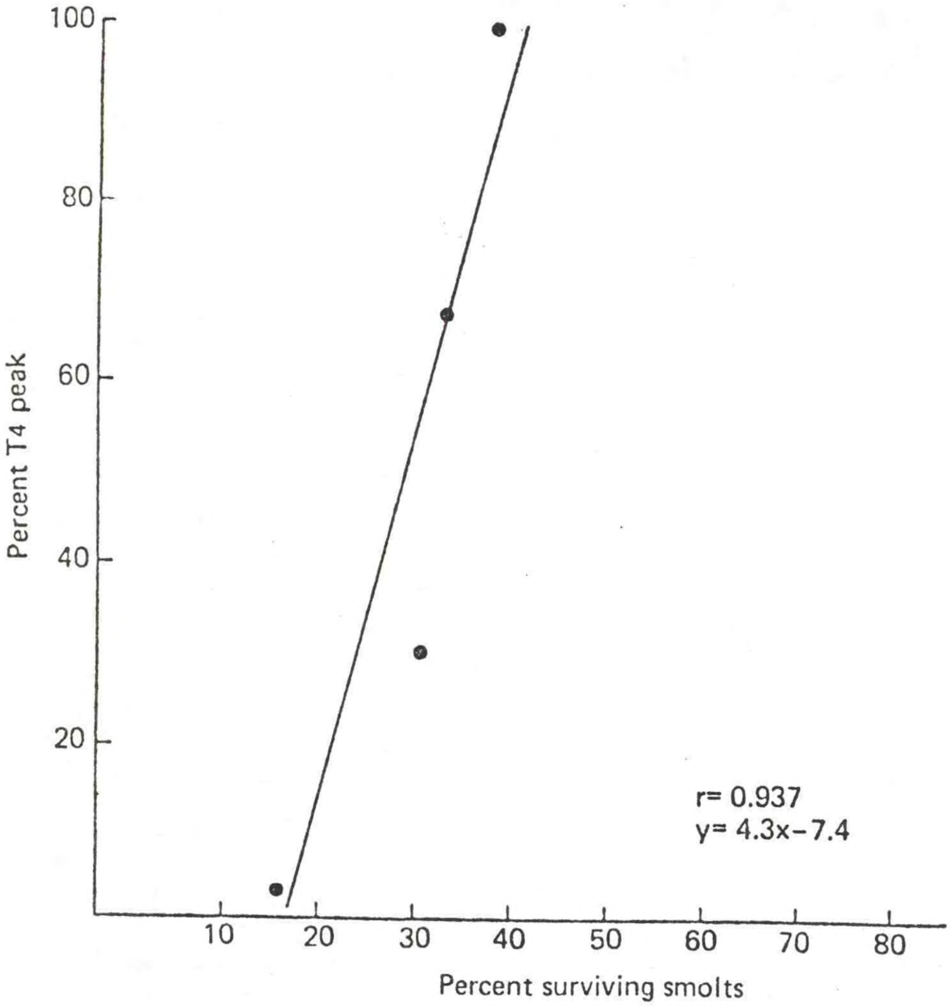


Figure 13.--Regression and analysis of the relationship between plasma T_4 concentrations and percent surviving smolts at termination of study in yearling baseline coho salmon test groups.

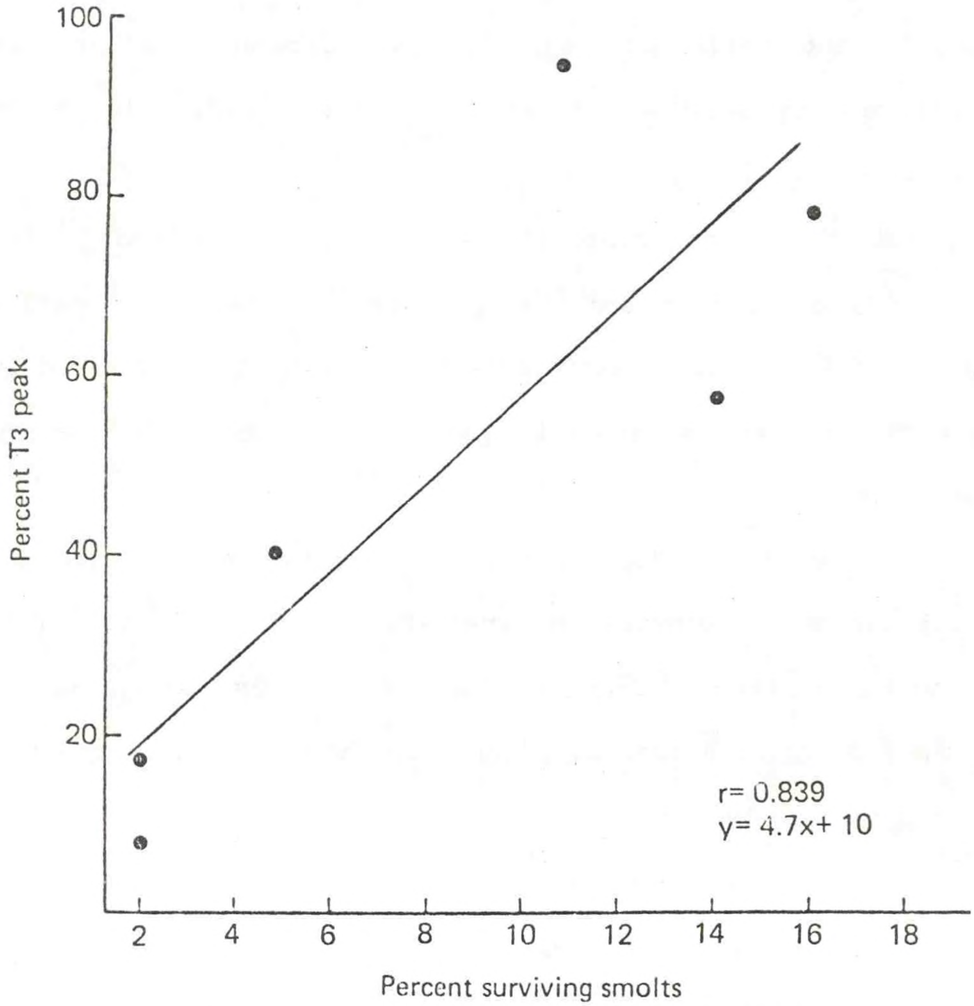


Figure 14.--Regression analysis of the relationship between plasma T_3 concentrations and percent surviving smolts at termination of study in 0-age baseline coho salmon test groups.

SYNOPSIS

Coho Salmon Studies - Columbia River Hatcheries

Cooperative studies between NMFS and State Fisheries agencies were continued in 1979 to examine the effect of size and time of release on the contribution of hatchery coho salmon. Our contribution to the study was to provide information on smoltification, migration, and seawater adaptation. Fish were released simultaneously from four hatcheries in May, June, and July.

In the study, results showed that coho salmon held in hatcheries beyond their normal smolting period (late April and May) experienced a decrease in smolting characteristics. However, if released into the river, the fish appeared to resmolt and migrated rapidly past the sampling site at Jones Beach.

A sample of fish from each hatchery at the time of release was transported to seawater for evaluation. Fish released at about the same size but at three different time periods (May, June, and July) generally showed better seawater adaptation in the May release groups than those in the June or July groups.

Chinook Salmon Studies - Columbia River Hatcheries

Chinook salmon were emphasized in the 1979 study. Fish used in our study were part of ongoing State and Federal hatchery evaluation programs. As with coho salmon, our contribution to the various studies was to provide smoltification, migration, and seawater adaptation information.

Results showed that some populations of chinook salmon show no physiological signs of smoltification; yet, when released into a river, at least a portion of the population showed active smoltification and migration. This and other evidence suggests that hatchery rearing conditions affect the smoltification and out-migration process in salmonids.

Out-migration of chinook salmon was generally more rapid with elevations in gill $Na^{+}-K^{+}$ ATPase. It is our opinion that the "sodium pump" activity in gills of fish can be fully functional by the time seawater is reached even if activity is initially low, depending upon migratory distance and time.

Fall chinook salmon as with coho salmon were transferred to seawater for adaptation studies. The experiments generally showed that the larger the fish are and the later they enter seawater the better they adapt to seawater. However, this relationship was partially dependent on the freshwater disease history, rearing environment, and status of smoltification when held in seawater. Fall chinook salmon generally showed osmoregulatory dysfunction within the first 10-15 days after seawater entry. Based upon this information, a 30-day holding period is sufficient to evaluate seawater adaptation in fall chinook salmon.

Steelhead Studies - Columbia River Hatcheries

Two populations of steelhead were evaluated as to their status of smoltification and seawater adaptation. No statistically significant relationships existed between gill $Na^{+}-K^{+}$ ATPase and plasma thyroid hormones in steelhead. This was in contrast to all of our previous observations with coho and chinook salmon.

Seawater adaptation was poor. It was found that seawater temperatures above 12°C may block smoltification and successful seawater adaptation in steelhead. This temperature has been shown to be critical for steelhead reared in fresh water.

Coho Salmon Baseline Studies - Montlake Laboratory

In 1977 coho salmon eggs were obtained from the Toutle Hatchery and transported to the NMFS Montlake Laboratory for hatching. The eggs were divided into two groups and were referred to as baseline fish. Fish in half of the population were accelerated using warm water to produce 0-age smolts (1978 study). The other half was reared using normal temperature regimes to produce yearling smolts.

Biochemical sampling was conducted in fresh water to determine status of smoltification. Results showed gill Na^{+}-K^{+} ATPase and plasma T_4 concentrations were higher in yearling than in the 0-age baseline coho salmon evaluated in 1978.

Ten groups of the yearling coho salmon were serially transferred to seawater from May to September 1977. Peak smoltification occurred in early May. As with the coho salmon from the Columbia River hatcheries, the time, size, and status of smoltification were related to seawater survival (Appendix B and F).

Evaluation of Methods to Determine Status of Smoltification in Salmonids

Yearling baseline coho salmon were employed to evaluate methods of smolt indexing (plasma T_3 and T_4 monovalent and divalent blood ions and swimming performance tests).

Statistically significant relationships were found between the area under the plasma T_4 curve for surviving smolts in yearling baseline coho salmon, i.e., (greater the area the better the survival), and the area under plasma T_3 curve and surviving smolts in the 0-age fish (Appendix F).

A statistically significant relationship was found between T_4 curves in fresh water and the number of surviving smolts at termination of study for Columbia River Hatchery coho and spring chinook salmon but not steelhead. No T_4 data were obtained on fall chinook salmon because of their small size at time of sampling. Due to the relationships between plasma thyroid hormone profiles in fresh water with surviving smolts in seawater, we continue to support the use of these measurements to predict the optimal time of seawater transfer for coho and chinook salmon but not steelhead.

Divalent and monovalent blood ions were analysed as indicators of smoltification. The divalent plasma electrolyte Ca^{++} was found to fluctuate in opposition to plasma T_4 concentration in coho and chinook salmon but not in steelhead, suggesting an antagonistic relationship between T_4 and prolactin in the genus Oncorhynchus.

Plasma Ca^{++} levels remained relatively constant at seawater entry. Plasma Mg^{++} levels showed little change in fresh water; however in seawater, Mg^{++} concentrations changed in a pattern similar to that of Na^+ and Cl^-. No statistically significant changes were observed for Na^+ or Cl^-; whereas, K^+, Ca^{++}, and Mg^{++} showed short transitory increases during the period of freshwater measurements in coho salmon. In general, plasma blood ions did not prove to be reliable indicators of smoltification at this time (Appendix F).

Baseline yearling coho salmon were used to determine smoltification status using swimming performance tests. Swimming performance tests were conducted in both fresh and seawater. No immediate deaths were attributed to swimming fatigue in either fresh or seawater. Delayed deaths did occur in seawater. A 7-day minimal holding period after stressing coho salmon is suggested in order to determine delayed mortality. At seawater entry, survival following swimming fatigue stress was significantly related to elevations in freshwater Na^+-K^+ ATPase and T_4 concentrations. Swimming fatigue type tests can be used to determine status of smoltification and seawater survival of coho salmon.

ACKNOWLEDGMENTS

We would like to extend our thanks to the Oregon Department of Fish and Wildlife, Washington Departments of Fisheries and Game, and the U.S. Fish and Wildlife Service for their cooperation in carrying out these studies. The logistics involved in conducting extensive field-laboratory surveys of this type are enormous. The task could not have been accomplished without the cooperation of the above agencies and particularly the individual hatchery managers and their crews.

LITERATURE CITED

Ellis, Richard, A. J. Novotny, and Lee W. Harrell.
1978. Case report of kidney disease in a wild chinook salmon, Oncorhynchus tshawytscha in the sea. J. Wildlife Dis. 14 p 120-123.

Flagg, T. A., and L. S. Smith.
1979. Appendix F: Changes in swimming performance, critical fatigue levels, and metabolic rates during the parr-smolt transformation of Toutle (accelerated underyearling) coho salmon (Oncorhynchus kisutch). Unpublished manuscript, 31 p., In FY 1978-79 Report, Project 817. A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Lorz, H. W., and B. P. McPherson.
1976. Effects of copper or zinc in fresh water on the adaptation to seawater and ATPase activity and the effects of copper on migratory disposition of coho salmon Oncorhynchus kisutch. J. Fish. Res. Bd. Can. 33(9), p 2023-2030.

Novotny, A. J.
1975. Net-pen culture of Pacific salmon in marine waters. Mar. Fish. Rev. 37(1), p 36-47.

PNRC Report.
1979. A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead. Unpublished manuscript. 403 p. In FY 1978-79 Report, Project 817. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA. 2725 Montlake Blvd. E., Seattle, WA 98112.

Schmidt-Nielsen, B.
1974. Osmoregulation: Effect of salinity and heavy metals. Fed. Proc. 33(10), p 2137.

Zaugg, W. S.
1979. Appendix A: Freshwater Na^{+}-K^{+} ATPase activities at hatcheries and Jones Beach. Unpublished manuscript, 46 p., In FY 1978-79 Report, Project 817. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Ser., NOAA. 2725 Montlake Blvd. E., Seattle, WA 98112.

Zaugg, W. S., B. L. Adams, and L. R. McLain.
1972. Steelhead migration: potential temperature effects as indicated by gill adenosine triphosphatase activities. Science 176:415:416.

APPENDIX A

SMOLTIFICATION STATUS, SEAWATER SURVIVAL, AND GILL Na^{+}-K^{+} ATPASE ACTIVITIES IN SALMONIDS

by

W. S. Zaugg

September 1980

INTRODUCTION

Studies in 1978 on gill Na^+-K^+ ATPase activities in several groups of salmon and steelhead from state and federal hatcheries in the Columbia River system were reported previously (Zaugg 1979). The present report discusses similar studies conducted during spring and summer 1979. Studies in 1979 included several additional groups of fish (Table 1) and a much greater effort was made to increase the number of gill Na^+-K^+ ATPase determinations on individual migrants captured in the Columbia River estuary. The objective of the study remained the same as in 1978; that is, to monitor changes in Na^+-K^+ ATPase activity of select groups of fish in an attempt to evaluate their state of smoltification at release and to relate smoltification state to migration time from the hatchery to the estuary.

METHODS AND MATERIALS

Gill filaments were obtained and processed and Na^+-K^+ ATPase activities were determined as previously described (Zaugg 1979). Kidney samples were assayed, similar to gill tissues, as to their Na^+-K^+ ATPase activity in select groups of fish. Gill and kidney Na^+-K^+ ATPase activities are reported as μmoles ATP hydrolyzed . μmg protein^{-1}.h^{-1}. Biochemical analyses were started prior to hatchery release and continued beyond release at those hatcheries where fish could be held over for sampling. Samples were also taken from out-migrating fish captured in the Columbia River Estuary at Jones Beach 76 km from the river's mouth.

Results and discussion are presented by species in a synopsis format. Seawater Na^+-K^+ ATPase profiles were established on select groups of fish. At or near the time of hatchery release, a random sample of fish were transported to the National Marine Fisheries Service's (NMFS) seawater

Table 1.--1979 Test Groups

Hatchery	Stock	Species	Release date	Date of seawater entry	Total elapsed days in seawater
Tucannon[c]	Skamania	Steelhead	5/17/79	5/15/79	188
Chelan[c]	Chelan	Steelhead	4/24/79	4/26/79	208
Washougal[b]	Cowlitz	Coho	5/7/79	5/8/79	191
Washougal	Cowlitz	Coho	6/7/79	6/8/79	164
Washougal	Cowlitz	Coho	7/6/79	7/9/79	133
Toutle[b]	Toutle	Coho	5/7/79	5/8/79	190
Toutle	Toutle	Coho	6/7/79	6/14/79	158
Toutle	Toutle	Coho	7/7/79	7/9/79	128
Cascade[a]	Sandy	Coho	5/7/79	5/8/79	191
Cascade	Sandy	Coho	6/7/79	6/8/79	164
Cascade	Sandy	Coho	7/7/79	7/9/79	133
Big Creek[a]	Big Creek	Coho	5/7/79	5/8/79	190
Big Creek	Big Creek	Coho	6/7/79	6/8/79	158
Big Creek	Big Creek	Coho	7/7/79	7/9/79	128
Leavenworth[d]	Carson	Spring Chinook	4/26/79	4/26/79	208
Carson[d]	Carson	Spring Chinook	5/8/79	5/2/79	202
Elokomin[b]	Elokomin	Fall Chinook	6/15/79	6/14/79	165
Kalama Falls[b]	Kalama Falls	Fall Chinook	6/22/79 7/12/79	---- 7/17/79	---- 132
Toutle	Green River	Fall Chinook	6/17/79	6/26/79	153
Washougal & Toutle	Washougal	Fall Chinook	6/14/79	6/14/79	165
Bonneville[a]	Snake River	Fall Chinook	10/30/78 3/13/79	---- 3/19/79	---- 156
Bonneville	Bonneville (Tules)	Fall Chinook	5/29/79	5/30/79	180

Table 1.--Contd.

Hatchery	Stock	Species	Release date	Date of seawater entry	Total elapsed days in seawater
Little White Salmon[d]	Little White Salmon	Fall Chinook	6/22/79	6/27/79	153
Willard[d]	Little White Salmon	Fall Chinook	7/12/78	7/11/79	107
Willard	Little White Salmon	Fall Chinook	11/14/78	10/31/79	295
Willard	Little White Salmon	Fall Chinook	4/19/79	4/2/79	124
Spring Creek[d]	Spring Creek	Fall Chinook	3/20/79	3/21/79	154
Spring Creek	Spring Creek	Fall Chinook	4/20/79	4/2/79	220
Spring Creek	Spring Creek	Fall Chinook	5/18/79	5/21/79	189
Spring Creek	Spring Creek	Fall Chinook	8/13/79	8/13/79	105
Big White Salmon[d]	Spring Creek	Fall Chinook	5/21/79	5/21/79	189

Operated by:

a/ Oregon Department of Fish and Wildlife
b/ Washington Department of Fisheries
c/ Washington Department of Game
d/ U.S. Fish and Wildlife Service

facility near Manchester, Washington for seawater adaptation studies (Appendix B). Fish were sampled daily for the first 8 days, at day 30, and at termination of seawater holding in November 1979.

RESULTS AND DISCUSSION

The results of this year's study are presented by a Smolt Evaluation Summary (SES) and an explanatory discussion for each test group.

Steelhead

Tucannon Hatchery (SES 1)

The gill Na^+-K^+ ATPase profile of summer-run steelhead from the Tucannon Hatchery was qualitatively similar to that observed in 1978 with a distinct peak in enzyme activity in early May (Figure 1). A typical development of Na^+-K^+ ATPase activity was observed when these fish were transferred to seawater at Manchester. Little change occurred until the fourth day when activity began to rise (Figure 1). The average value at termination of the experiment in seawater was 36.6 μmoles Pi . mg $prot^{-1}.h^{-1}$.

Chelan Hatchery (SES 2)

Gill Na^+-K^+ ATPase in steelhead from Chelan Hatchery showed only a small rise in activity in late April (Figure 1). The absence of a greater increase in activity may have resulted from water temperatures which remained at the upper limit (13°C) for good smoltification during late April and May. Chelan steelhead were much larger than Tucannon fish when representative samples were placed in seawater at Manchester. Large size, which seems to alleviate the initial physiological shock of seawater adaptation, may have been a major reason why no elevation of gill Na^+-K^+ ATPase activity occurred until the seventh day (Figure 1). However, final Na^+-K^+ ATPase activity was very high (51.2) compared to Tucannon fish (36.6).

SMOLT EVALUATION SUMMARY 1

HATCHERY: TUCANNON SPECIES: STEELHEAD STOCK: SKAMANIA

DIET: ----- POND #: 4

RELEASE DATE: 17 May 1979 CODED WIRE TAG: W-LB-PK-LB

NUMBER RELEASED: 22,058 (Barged) BRAND: RAY

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
6.7	8 May	25.1	8 May	~ 18	17 May

In seawater:

Number of days:	1	2	3	4	5	6	7	8	30	Final[a]
Na^+-K^+ ATPase:	15.9	14.8	16.2	21.7	18.1	25.1	25.3	22.8	27.0	36.6
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	43.1	31.0 - 52.3
Fork length (mm):	172	150 - 181
Date:	22 May	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	19 May	30 May				
Number of fish:	27	1				
Mean fork length (mm):	179	180				
Mean Na^+-K^+ ATPase:	--	--				
Mean Plasma T_3:	--	--				
Mean Plasma T_4:	--	--				

a/ Final = 188 days

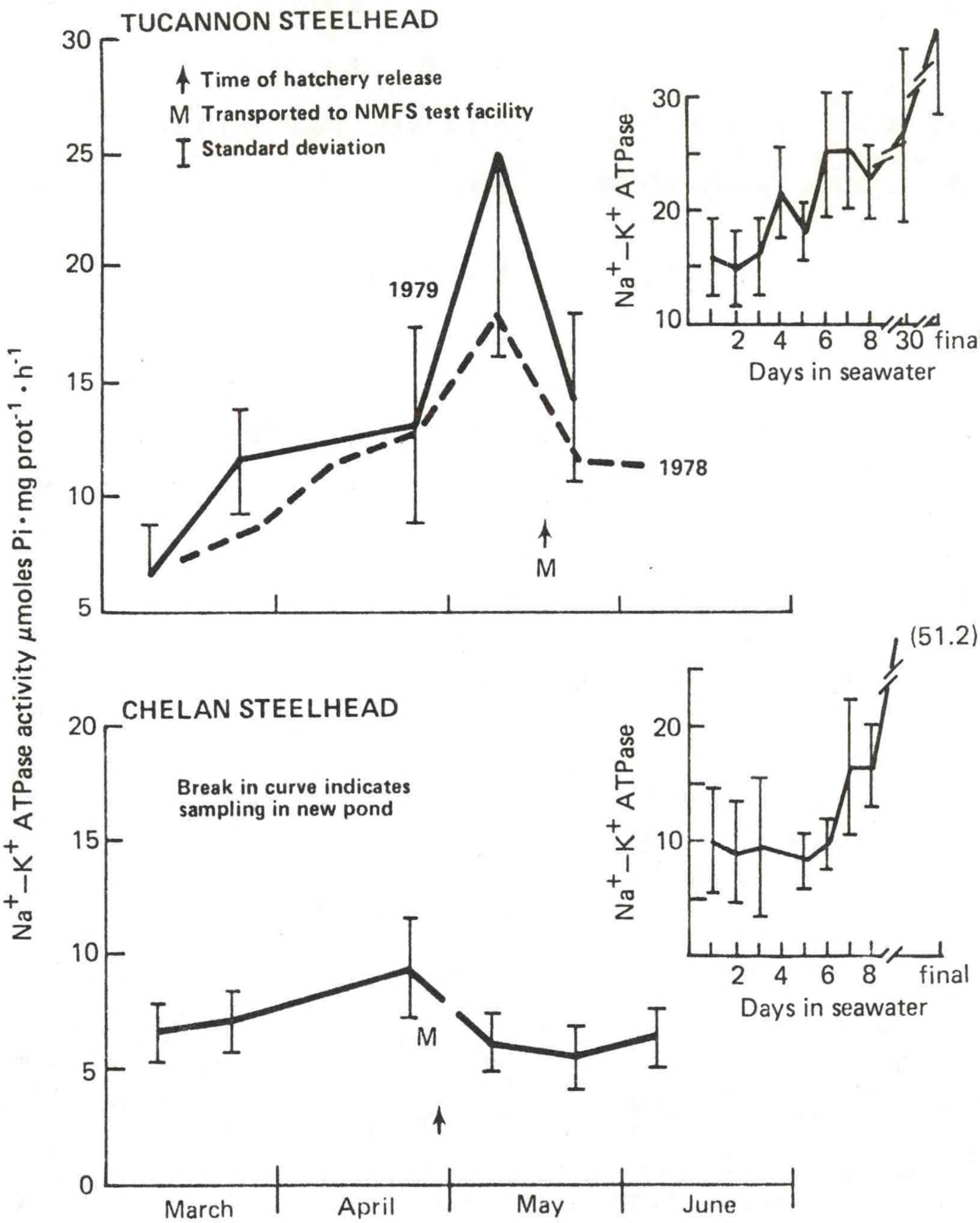


Figure 1 Gill Na^{+}-K^{+} ATPase activities in Tucannon (top) and Chelan (bottom) steelhead in both fresh and seawater.

SMOLT EVALUATION SUMMARY 2

HATCHERY: CHELAN SPECIES: STEELHEAD STOCK: CHELAN

DIET: -----

POND #: 3 and 5

RELEASE DATE: 24 Apr 80 (Barged)

CODED WIRE TAG: W-LB-RD (Pond 3)
W-LB-OR (Pond 5)

NUMBER RELEASED: 22,834 (WH-LB-OR)
24,335 (WH-LB-RD)

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
5.5	22 May	9.4	23 Apr	~ 8	28 Apr

In seawater:

Number of days:	1	2	3	5	6	7	8	Final[a/]		
Na^+-K^+ ATPase:	9.9	8.9	9.5	8.3	9.6	16.5	16.6	51.2		
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	98.1	59.7 - 145.8
Fork length (mm):	208	184 - 246
Date:	23 Apr	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	30 Apr	1 May		30 Apr	1 May	17 May
Number of fish:	4	10		1	6	1
Mean fork length (mm):	199	217		194	172	220
Mean Na^+-K^+ ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						
Tag	WH-LB-RD			WH-LB-OR		

a/ Final = 208 days

Coho Salmon

Serial releases of coho salmon were made this year at four hatcheries. Tagged fish were released in May, June, and July at approximately the same size, from the Cascade and Big Creek Hatcheries in Oregon and the Toutle and Washougal Hatcheries in Washington. Gill Na^+-K^+ ATPase activities were determined on each of these groups during hatchery residence and on some individual migrants from Cascade, Washougal, and Toutle Hatcheries captured at Jones Beach after release. Profiles of enzyme activities were similar at all four hatcheries, showing high levels in late April and early May with a later decline to presmolt values by late May and early June. Migration patterns of fish released in June and July were similar at all three hatcheries upstream from the Jones Beach facility. Although fish released in June and July were judged to be in a parr state on the basis of appearance and low gill Na^+-K^+ ATPase activity, they nevertheless migrated quite rapidly. However, all captured migrants assayed had elevated levels of gill Na^+-K^+ ATPase and displayed visual characteristics of re-smoltification (i.e. beginning to lose parr marks and take on silvery coloration). It is concluded that some factor or factors in the hatchery environment caused these coho salmon to revert to parr from a smolted stage, but that the process was reversible once they were liberated into a natural stream. At the present time these factors are unidentified but may include pond density and/or the actual physical inability to move downstream in a raceway after smoltification had occurred.

Washougal Hatchery (SES 3, 4, & 5)

Mean gill Na^+-K^+ ATPase activities for each of the three release groups and data on migrant captures at Jones Beach are presented in Figure 2. A total of 168 migrants were caught from tagged fish released in May, while 238 and 383 were captured from the June and July releases (Table 2). Decreases in river flows (Table 3) probably contributed to greater numbers of migrants being captured in June and July, but migration rate is also a factor.

The length of time required for migration, as estimated by the time periods during which migrants were caught, decreased with later releases in spite of lower river flows. Migrants from the May release were caught for a period of 46 days (8 May - 22 June), from the June release for 33 days (11 June - 13 July), and from the July release for only 10 days (11 - 20 July). Higher gill Na^+-K^+ ATPase activities in migrants caught on 20 June than caught on 13 June, and on 16 July than on 12 July suggest that the fish were in the process of developing saltwater tolerance (smoltification), a process which appears to have begun upon release from the hatchery and progressed with time and movement seaward. Higher mean Na^+-K^+ ATPase activities observed in the July migrants than observed in those captured in June may reflect the accelerating influence of warmer water (Table 2) on the smoltification process (Zaugg and McLain 1976).

SMOLT EVALUATION SUMMARY 3

HATCHERY: WASHOUGAL

SPECIES: COHO

STOCK: WASHOUGAL

DIET:

POND #: 18 and 19

RELEASE DATE: 7 May 1979

CODED WIRE TAG: 63-19-23 (No. 74,378)
63-19-24 (No. 80,652)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
5.4	4 Apr	15.3	1 May	~ 17	7 May

In seawater:

Number of days:	10									
Na^+-K^+ ATPase:	16.6									
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	22.6	13.5 - 303
Fork length (mm):	127	110 - 142
Date:	1 May	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	17 May	24 May				
Number of fish:	3	2				
Mean fork length (mm):	137	140				
Mean Na^+-K^+ ATPase:	20.3	23.4				
Mean Plasma T_3:	6.3	4.5				
Mean Plasma T_4:	34.1	12.6				

SMOLT EVALUATION SUMMARY 4

HATCHERY: WASHOUGAL | SPECIES: COHO | STOCK: WASHOUGAL

DIET: ----- | POND #: 20 and 21

RELEASE DATE: 7 June 1979 | CODED WIRE TAG: 63-19-25 (No. 73,010)
63-19-26 (No. 82,887)

NUMBER RELEASED: | BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.4	4 Apr	17.6	15 May	~ 6	7 Jun

In seawater:

Number of days:	No sampling									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	27.9	20.1 - 38.9
Fork length (mm):	139	123 - 152
Date:		

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	13 Jun	20 Jun				
Number of fish:	10	11				
Mean fork length (mm):	136	131				
Mean Na^+-K^+ ATPase:	10.7	15.2				
Mean Plasma T_3:	---	---				
Mean Plasma T_4:	---	---				

SMOLT EVALUATION SUMMARY 5

HATCHERY: WASHOUGAL

SPECIES: COHO

STOCK: WASHOUGAL

DIET: -----

POND #: 22 and 23

RELEASE DATE: 6 Jul 1979

CODED WIRE TAG: 63-19-27 (No. 81,028)
63-19-34 (No. 82,066)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.4	4 Apr	14.5	15 May	~ 5.6	6 Jul

In seawater:

Number of days:	No	Sampling								
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	24.3	17.1 - 29.8
Fork length (mm):	130	122 - 144
Date:	6 July	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	12 Jul	16 Jul				
Number of fish:	20	15				
Mean fork length (mm):	139	127				
Mean Na^+-K^+ ATPase:	15.5	18.4				
Mean Plasma T_3:	8.4	(8 samples only)				
Mean Plasma T_4:	14.3	(8 samples only)				

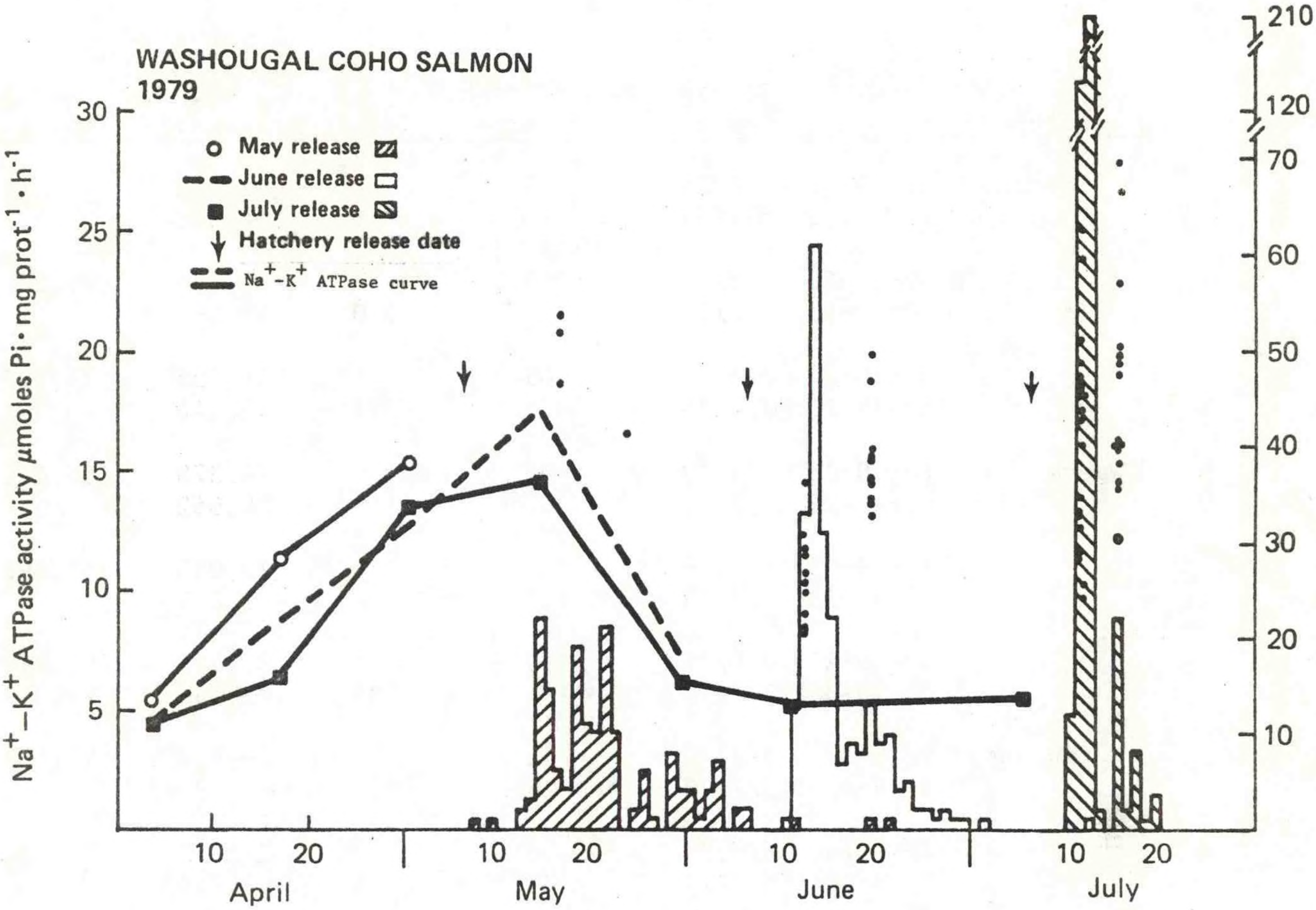


Figure 2 Gill Na^+-K^+ ATPase activities in Washougal coho salmon and numbers of migrants caught at Jones Beach. Arrows indicate releases on 7 May, 7 June, and 7 July. Single points (.) show gill Na^+-K^+ ATPase activities for individual migrants caught at Jones Beach.

Table 2.--Coho salmon from Toutle, Washougal, and Cascade hatcheries caught at Jones Beach - 1979.

Hatchery	CWT No.	Release date	No. of fish captured	Total	No. released	Total released
Toutle	63-19-11	5/7/79	46		42,422	77,110
	63-19-12	5/7/79	40	86	34,688	
	63-17-58	6/7/79	107		39,770	80,268
	63-19-13	6/7/79	103	210	40,498	
	63-19-28	7/7/79	109		34,756	75,902
	63-19-29	7/7/79	95	204	41,146	
Washougal	63-19-23	5/7/79	81		74,378	155,030
	63-19-24	5/7/79	87	168	80,652	
	63-19-25	6/7/79	120		73,010	155,897
	63-19-26	6/7/79	118	238	82,887	
	63-19-27	7/6/79	192		81,028	163,094
	63-19-34	7/6/79	191	383	82,066	
Cascade	7-19-8	5/7/79	18		29,813	58,708
	7-19-11	5/7/79	18	36	28,895	
	7-19-7	6/7/79	36		29,743	58,557
	7-19-10	6/7/79	32	68	28,814	
	7-19-9	7/7/79	50		28,216	56,784
	7-19-12	7/7/79	56	106	28,568	

Table 3.--Columbia River water flow and temperature - 1979

Date	Water flow at Bonneville Dam (KCFS)	River temperature at Jones Beach (°C)
10 May 1979	387	12.2
7 June 1979	255	15.5
5 July 1979	126	17.7

Toutle Hatchery (SES 6, 7, 8)

Gill Na^+-K^+ ATPase activity and migrant capture information are presented in Figure 3, SES 6, 7, and 8; and Table 2. These data lead to the same conclusions as presented in the previous section on coho salmon from the Washougal Hatchery. The response of gill Na^+-K^+ ATPase activity to seawater exposure in the three release groups is shown in Figure 4.

Cascade Hatchery (SES 9, 10, 11)

Data collected on gill Na^+-K^+ ATPase activities and migrant capture are presented in Figure 5, SES 9, 10, and 11; and Table 2. Fewer migrants were captured from these releases than from the Toutle and Washougal groups. Consequently, the information obtained on migrants is insufficient to justify the same conclusions that were reached for coho from Toutle and Washougal. However, the data obtained are not inconsistent with those conclusions.

SMOLT EVALUATION SUMMARY 6

HATCHERY: TOUTLE SPECIES: COHO STOCK: TOUTLE

DIET: OMP POND #: 16 and 17

RELEASE DATE: 7 May 1979 CODED WIRE TAG: 63-19-11 (No. 42,422)
63-19-12 (No. 34,688)

NUMBER RELEASED: BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot mg\ protein^{-1} \cdot hr^{-1}$)

At hatchery:

Low	Date	High	Date	At release	Date
8.8	12 Apr	10.8	4 May	~ 11	7 May

In seawater:

Number of days:	1	2	3	4	5	6	7	8	30	Final[a/]
Na^+-K^+ ATPase:	11.9	9.4	9.1	10.8	19.6	20.1	22.6	25.3	42.7	29.8
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	24.5	15.3 - 32.4
Fork length (mm):	132	112 - 145
Date:	4 May	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	17 May	24 May				
Number of fish:	3	2				
Mean fork length (mm):	136	130				
Mean Na^+-K^+ ATPase:	19.9	26.2				
Mean Plasma T_3:	5.3	7.1				
Mean Plasma T_4:	25.0	21.0				

a/ Final = 190 days

SMOLT EVALUATION SUMMARY 7

HATCHERY:	TOUTLE	SPECIES:	COHO	STOCK:	TOUTLE
DIET:	OMP	POND #:	15 and 18		
RELEASE DATE:	7 June 1979	CODED WIRE TAG:	63-19-13 (No. 40,498) 63-17-58 (No. 39,770)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
6.8	12 Apr	9.5	18 May	~ 7	7 Jun

In seawater:

Number of days:	1	2	3	4	5	6	7	8	30	Final[a/]
Na^+-K^+ ATPase:	4.6	4.7	7.7	10.7	11.8	14.2	17.1	19.4	30.2	38.7
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	24.4	15.2 - 34.6
Fork length (mm):	133	119 - 146
Date:	6 Apr	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	13 Jun					
Number of fish:	16					
Mean fork length (mm):	133					
Mean Na^+-K^+ ATPase:	12.6					
Mean Plasma T_3:						
Mean Plasma T_4:						

a/ Final = 158 days

SMOLT EVALUATION SUMMARY 8

HATCHERY: TOUTLE | SPECIES: COHO | STOCK: TOUTLE

DIET: OMP | POND #: 19 and 20

RELEASE DATE: 7 July 1979 | CODED WIRE TAG: 63-19-28 (No. 34,756)
63-19-29 (No. 41,146)

NUMBER RELEASED: | BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
3.5	5 Jul	10.5	4 May	~3.5	7 Jul

In seawater:

Number of days:	1	3	4	Final[a/]						
Na^+-K^+ ATPase:	3.1	2.3	6.4	26.1						
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	24.5	14.7 - 30.6
Fork length (mm):	133	114 - 146
Date:		

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	12 Jul	16 Jul				
Number of fish:	4	15				
Mean fork length (mm):	138	134				
Mean Na^+-K^+ ATPase:	11.3	17.1				
Mean Plasma T_3:	12.0	(one fish only)				
Mean Plasma T_4:	49.8	(one fish only)				

a/ Final = 128 days

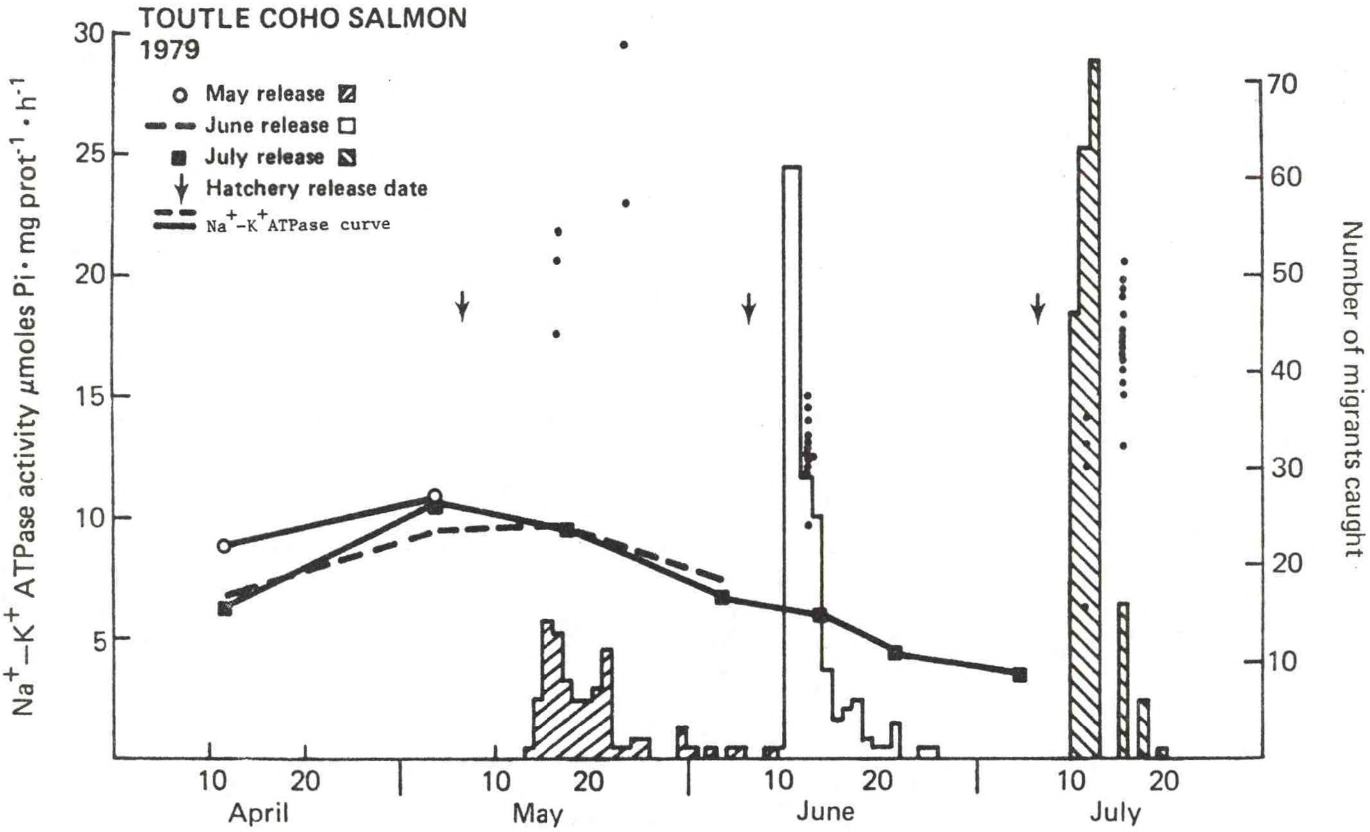


Figure 3 Gill Na^{+}-K^{+} ATPase activities in Toutle coho salmon and numbers of migrants caught at Jones Beach. Arrows indicate releases on 7 May, 7 June, and 7 July. Single points (.) show Na^{+}-K^{+} ATPase activities for individual migrants caught at Jones Beach.

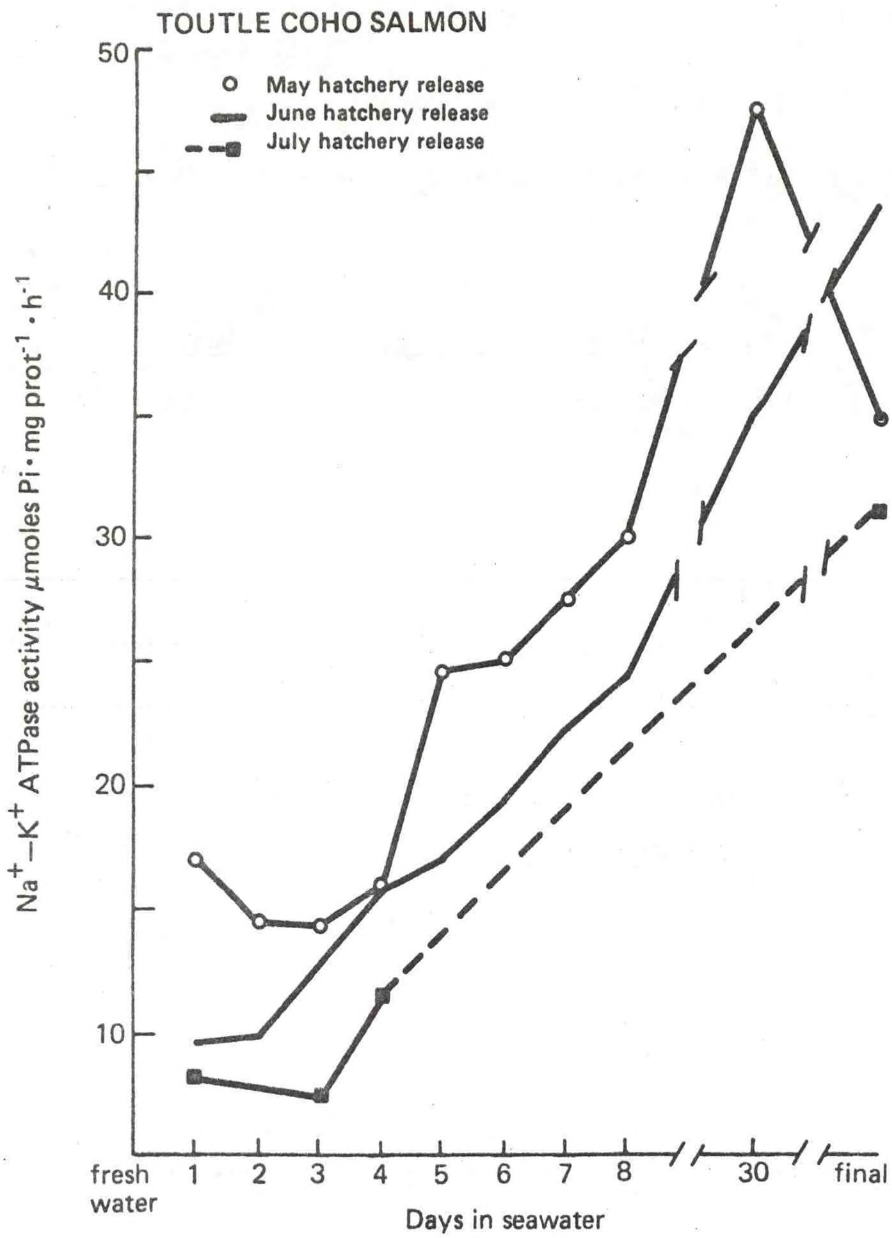


Figure 4 Gill Na^{+}-K^{+} ATPase activities in Toutle coho salmon exposed to seawater. See Table 1 for date of seawater entry and termination.

SMOLT EVALUATION SUMMARY 9

HATCHERY:	CASCADE	SPECIES:	COHO	STOCK:	
DIET:	-----	POND #:	6 and 9		
RELEASE DATE:	7 May 1979	CODED WIRE TAG:	7-19-8 (No. 29,813) 7-19-11 (No. 28,895)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg $protein^{-1}$ · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.9	3 Apr	11.5	30 Apr	~ 12	7 May

In seawater:

Number of days:	10									
Na^+-K^+ ATPase:	22.7									
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	22.2	14.6 - 34.4
Fork length (mm):	129	110 - 151
Date:	30 April	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	17 May					
Number of fish:	1					
Mean fork length (mm):	125					
Mean Na^+-K^+ ATPase:	21.1					
Mean Plasma T_3:	2.8					
Mean Plasma T_4:	14.1					

SMOLT EVALUATION SUMMARY 10

HATCHERY:	CASCADE	SPECIES: COHO	STOCK:
DIET:	-----	POND #: 5 and 8	
RELEASE DATE:	7 June 1979	CODED WIRE TAG: 7-19-7 (No. 29,743) 7-19-10 (No. 28,814)	
NUMBER RELEASED:		BRAND:	

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
5.0	3 Apr	12.1	30 Apr	~ 5	7 Jun

In seawater:

Number of days:	No sampling									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	21.0	14.8 - 30.8
Fork length (mm):	127	112 - 143
Date:	25 May	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	13 Jun	20 Jun				
Number of fish:	1	2				
Mean fork length (mm):	121	125				
Mean Na^+-K^+ ATPase:	13.3	26.3				
Mean Plasma T_3:	-----	3.2	(one fish only)			
Mean Plasma T_4:	-----	11.7	(one fish only)			

SMOLT EVALUATION SUMMARY 11

HATCHERY:	CASCADE	SPECIES: COHO	STOCK:
DIET:	-----	POND #: 7 and 10	
RELEASE DATE:	7 July 1979	CODED WIRE TAG: 7-19-9 (No. 28,216) 7-19-2 (No. 28,568)	
NUMBER RELEASED:		BRAND:	

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.5	3 Apr	12.0	14 May	~ 5	7 July

In seawater:

Number of days:	No sampling									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	20.1	14.1 - 27.2
Fork length (mm):	125	110-142
Date:	2 July	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	12 Jul	23 Jul				
Number of fish:	6	1				
Mean fork length (mm):	133	127				
Mean Na^+-K^+ ATPase:	16.7	17.6				
Mean Plasma T_3:	12.6	(one fish only)				
Mean Plasma T_4:	18.4	(one fish only)				

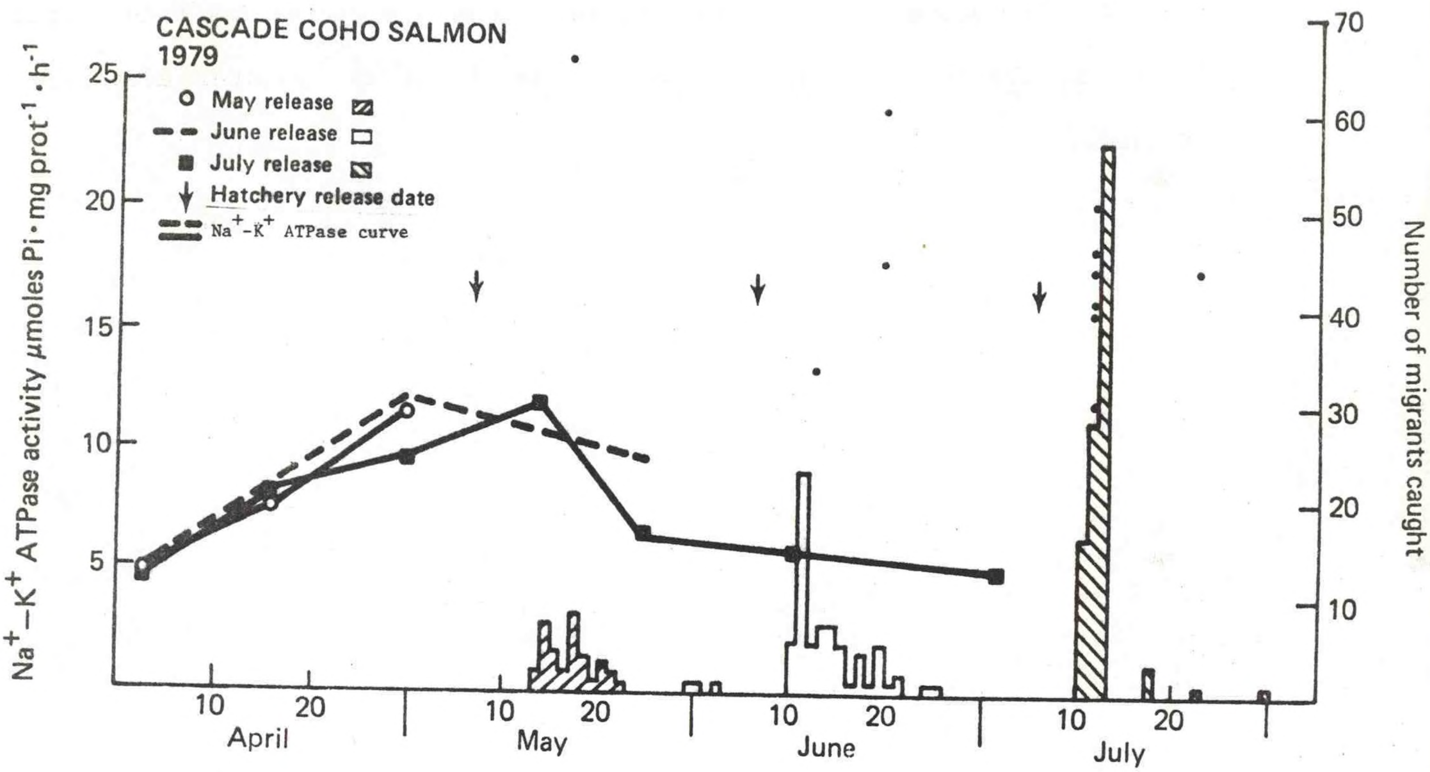


Figure 5 Gill Na^{+}-K^{+} ATPase activities in coho salmon from the Cascade Hatchery and numbers of migrants captured at Jones Beach. Arrows indicate releases on 7 May, 7 June, and 7 July. Single points (.) show Na^{+}-K^{+} ATPase activities for individual migrants caught at Jones Beach.

Big Creek Hatchery (SES 12, 13, & 14)

Gill Na^+-K^+ ATPase values for the 1979 test groups are presented in Figure 6 with values from 1978 for comparison. Since Big Creek Hatchery is downstream from Jones Beach, no migrants were captured. Gill Na^+-K^+ ATPase activities for seawater adapting fish are plotted in Figure 7. Kidney Na^+-K^+ ATPase activities showed a dramatic drop as fish became acclimated to seawater. This is a reflection of the decreasing role of the kidney as the primary location for ion excretion as seawater adaptation proceeds.

SMOLT EVALUATION SUMMARY 12

HATCHERY:	BIG CREEK	SPECIES:	COHO	STOCK:	BIG CREEK
DIET:	-----	POND #:	10B and 11B		
RELEASE DATE:	7 May 1979	CODED WIRE TAG:	7-19-3 (No. 29,207) 7-19-5 (No. 28,283)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
9.8	6 Apr	17.8	2 May	~ 18	7 May

In seawater:

Number of days:	1	2	3	4	5	6	7	8	30	Final[a]
Na^{+}-K^{+} ATPase:	16.1	14.6	21.9	20.1	19.6	23.0	25.7	21.2	48.5	21.1
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	23.5	16.0 - 33.3
Fork length (mm):	129	114 - 145
Date:	2 May	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^{+}-K^{+} ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

a/ Final = 190 days

SMOLT EVALUATION SUMMARY 13

HATCHERY: BIG CREEK — SPECIES: COHO — STOCK: BIG CREEK

DIET: -----

POND #: 10A and 11A

RELEASE DATE: 7 June 1979

CODED WIRE TAG: 7-19-4 (No. 29,039)
7-19-6 (No. 28,668)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
10.2	6 Apr	16.7	2 May	~16	7 May

In seawater:

Number of days:	No samples									
Na^{+}-K^{+} ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	23.8	16.4 - 33.8
Fork length (mm):	129	115 - 144
Date:	31 May	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^{+}-K^{+} ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 14

HATCHERY: BIG CREEK

SPECIES: COHO

STOCK: BIG CREEK

DIET: -----

POND #: 9A and 9B

RELEASE DATE: 7 July 1979

CODED WIRE TAG: 7-19-1 (No. 28.923)
7-19-2 (No. 29,409)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i • mg $protein^{-1}$ • hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
7.9	5 July	17.3	2 May	~ 7.9	7 July

In seawater:

Number of days:	1	2	3	4	5	6	Final[a/]			
Na^+-K^+ ATPase:	9.3	11.2	10.1	16.2	--	20.0	35.4			
% Mortality:										
Na^+-K^+ ATPase:	33.1	34.3	27.5	16.5	19.8	8.3	(Kidney)			

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	23,4	15.9 - 35.8
Fork length (mm):	134	118 - 151
Date:	5 July	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^+-K^+ ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

a/ Final = 133 days

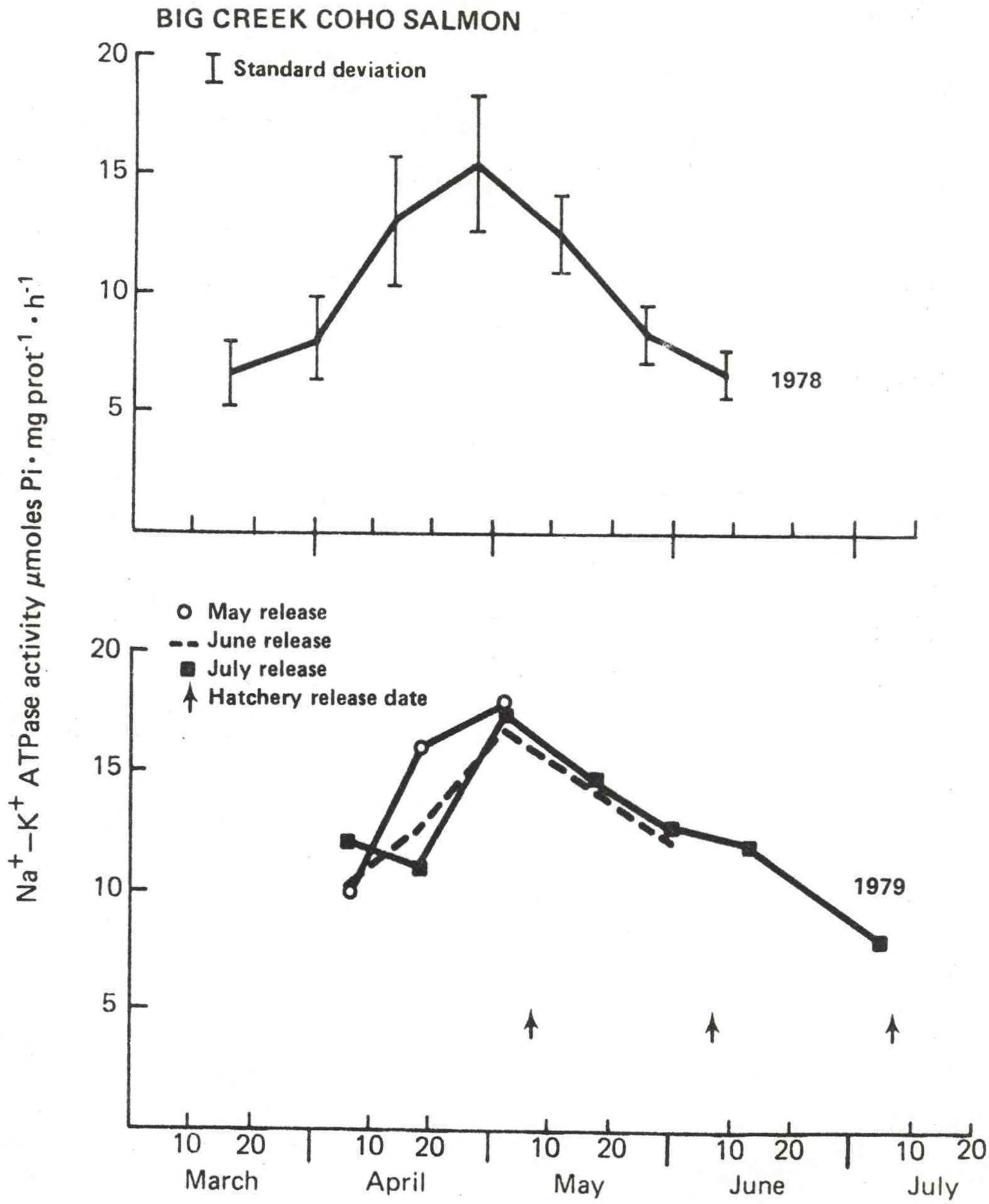


Figure 6 Gill Na^+-K^+ ATPase activities in Big Creek coho salmon in 1978 (top) and 1979 (bottom). Arrows show release dates on 7 May, 7 June and 7 July.

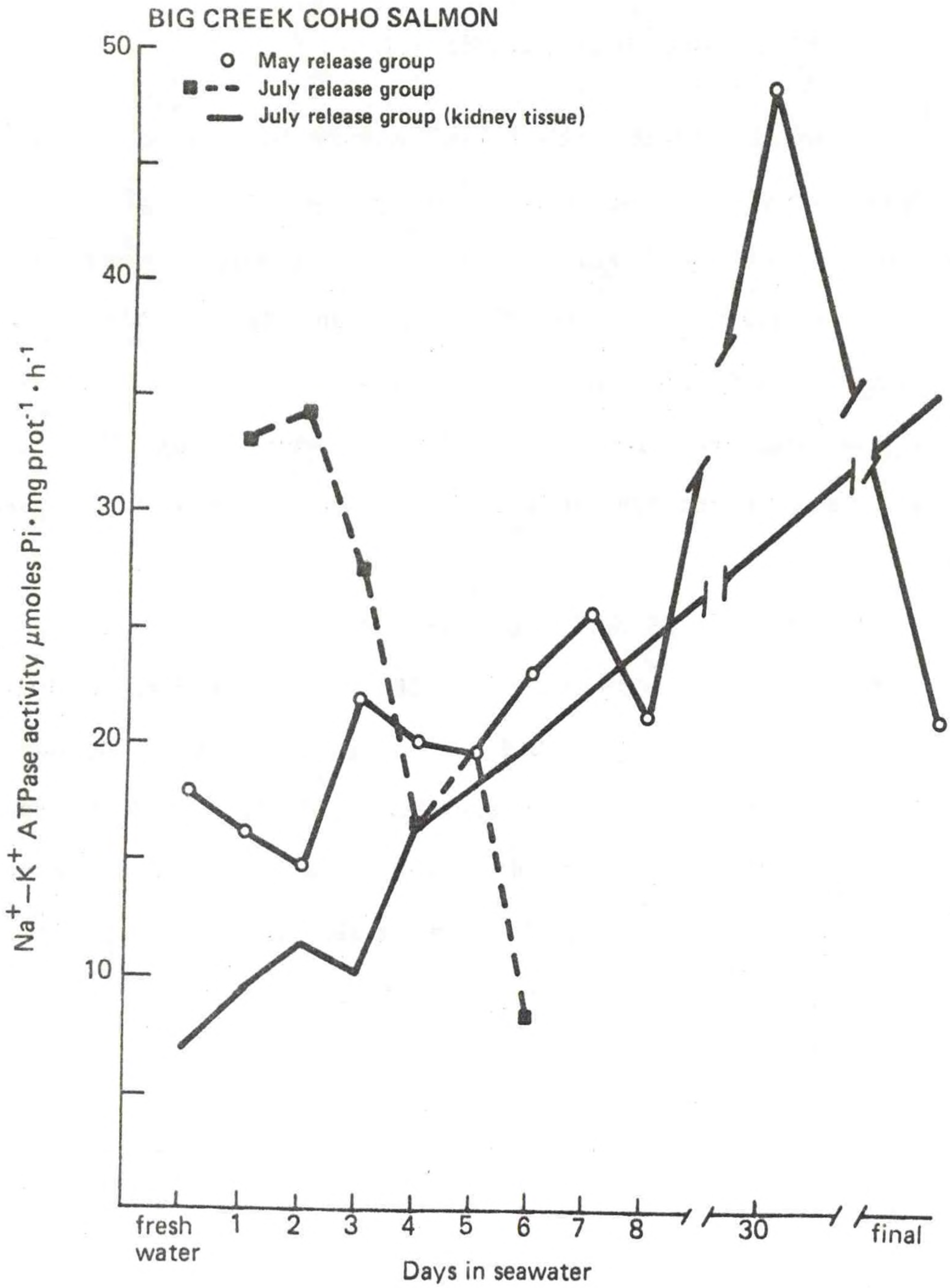


Figure 7 Gill and kidney Na^{+}-K^{+} ATPase activities in Big Creek coho salmon exposed to seawater. See Table 1 for date of seawater entry and termination.

Spring Chinook Salmon

Leavenworth National Fish Hatchery (SES 15)

A somewhat different gill Na^{+}-K^{+} ATPase profile was obtained for Leavenworth spring chinook salmon in 1979 than in 1978 (Figure 8). Differences in facilities used to hold fish for sampling beyond release may have had an influence on ability to maintain high activity. In 1978, post-release samples were taken from fish which had been moved inside the hatchery building and placed in a trough, whereas in 1979, fish for sampling were left outside in a small raceway at a very low population density.

Migrants from the 26 April release moved rapidly downstream, reaching Jones Beach by 12 May (Figure 8). Gill Na^{+}-K^{+} ATPase activities of fish caught on 24 May were exceptionally high (average 43.0), much higher than animals which had been in seawater (SES 15). This observation suggests that fish migrating distances long enough to permit full development of "salt pump" activity are completely ready, with respect to at least this physiological parameter, to make the transition to seawater.

SMOLT EVALUATION SUMMARY 15

HATCHERY: LEAVENWORTH

SPECIES: SPRING CHINOOK

STOCK: CARSON

DIET: -----

POND #: 23

RELEASE DATE: 26 Apr 1979

CODED WIRE TAG: 63-18-9

NUMBER RELEASED: 97,517

BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.6	9 Mar	16.3	21 May	~ 13.5	26 Apr

In seawater:

Number of days:	1	2	3	4	5	6	7	Final[a/]		
Na^{+}-K^{+} ATPase:	17.6	17.5	16.0	20.1	23.3	28.3	27.7	21.7		
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	25.5	15.0 - 38.9
Fork length (mm):	131	110 - 147
Date:	23 Apr	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	17 May	24 May				
Number of fish:	2	7				
Mean fork length (mm):	172	144				
Mean Na^{+}-K^{+} ATPase:	29.0	43.0				
Mean Plasma T_3:	4.2	5.9				
Mean Plasma T_4:	14.7	22.3				

Time period of capture: Tag 63-18-9, 12 May - 8 June

a/ Final = 208 days

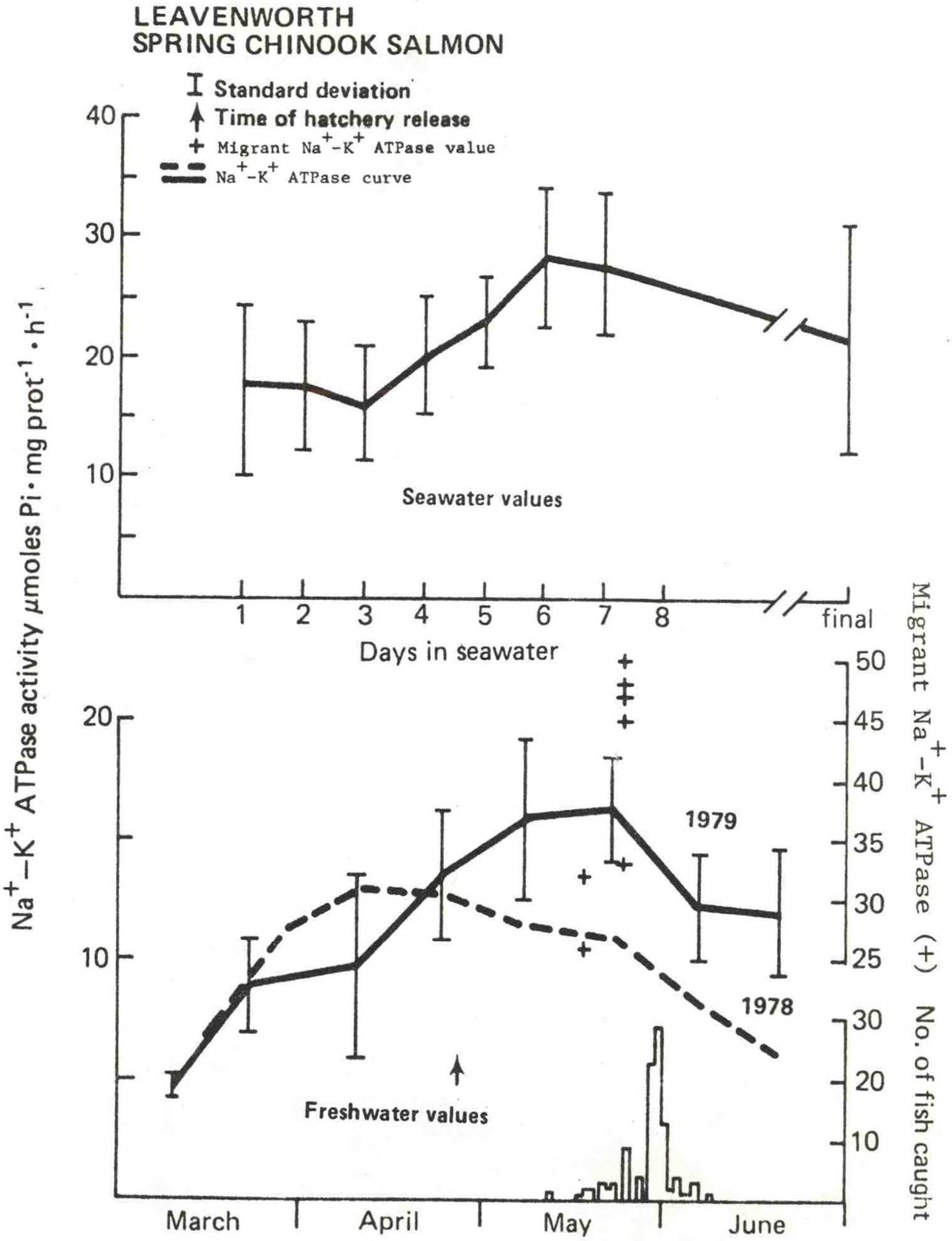


Figure 8 Gill Na^{+}-K^{+} ATPase activities in Leavenworth spring chinook salmon and numbers of migrants captured at Jones Beach. See Table 1 for date of seawater entry and termination.

Carson National Fish Hatchery (SES 16)

Gill Na^{+}-K^{+} ATPase activities were somewhat higher in 1979 than in 1978 (Figure 9). However, the time during which activity increased appeared to be the same in both years although sampling this year was not continued beyond release. These fish were released at Hammond, Oregon, which is located downstream from Jones Beach; consequently the migrants were not recovered.

SMOLT EVALUATION SUMMARY 16

HATCHERY: CARSON | SPECIES: SPRING CHINOOK | STOCK: CARSON

DIET: ----- | POND #: 42

RELEASE DATE: 8 May 1979 | CODED WIRE TAG: WH-LB-XR

NUMBER RELEASED: 38,553 (Hammond) | BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
9.4	6 Mar	20.4	1 May	~ 20	8 May

In seawater:

Number of days:	1	2	3	4	5	6	7	8	180	
Na^{+}-K^{+} ATPase:		17.0	21.7	17.0	25.0	21.5	31.1	31.7	27.8	
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	25.1	15.6 - 46.3
Fork length (mm):	127	112 - 158
Date:	1 May	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^{+}-K^{+} ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

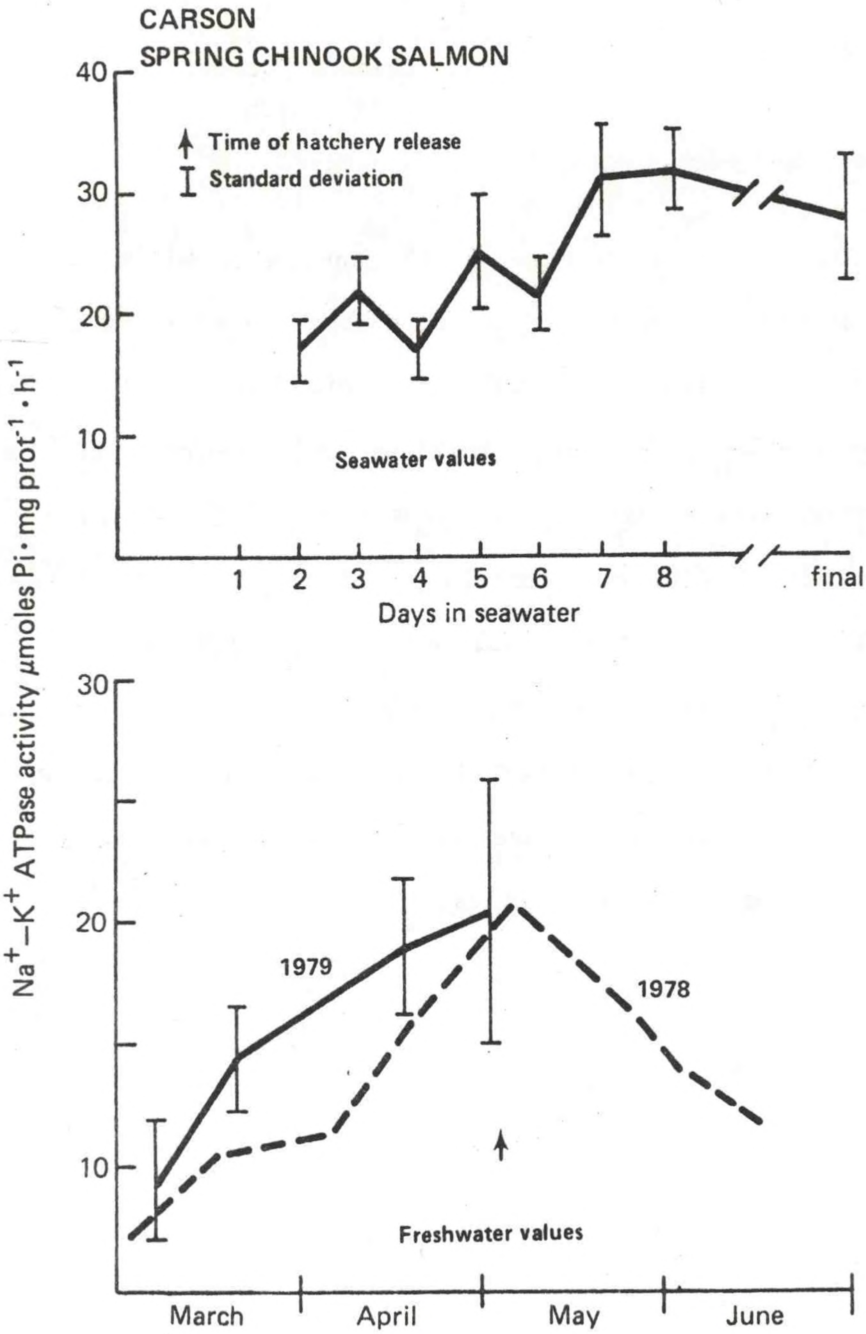


Figure 9 Gill Na^+-K^+ ATPase activities in Carson spring chinook salmon in both fresh and seawater.

Fall Chinook Salmon

Elokomin Hatchery (SES 17)

Just prior to release on 15 June, gill Na^{+}-K^{+} ATPase activities in fall chinook salmon at the Elokomin Hatchery began to increase (Figure 10). At time of release, a small number of fish were taken from the pond and placed inside the hatchery building in a wooden trough and sampling was continued. There was a wide range of Na^{+}-K^{+} ATPase activities in fish in the final (August) sampling, and the relation between average fork length of each 3-fish pool and Na^{+}-K^{+} ATPase activity is shown in Figure 10. These data suggest that at this time and under the existing holding conditions a minimum of about 88 mm fork length was required before elevated gill Na^{+}-K^{+} ATPase activity and that larger fish were capable of developing higher activities.

SMOLT EVALUATION SUMMARY 17

HATCHERY: ELOKOMIN

SPECIES: FALL CHINOOK

STOCK: ELOKOMIN

DIET:

POND #: 22

RELEASE DATE: 15 June 1979

CODED WIRE TAG: 63-18-56

NUMBER RELEASED: 22,786

BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
12.0	24 May	17.0	27 Jun	~ 16	13 Jun

In seawater:

Number of days:	NO SAMPLING									
Na^{+}-K^{+} ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	4.6	2.5 - 6.5
Fork length (mm):	73	60 - 82
Date:	13 Jun	

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	NO DATA					
Number of fish:						
Mean fork length (mm):						
Mean Na^{+}-K^{+} ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

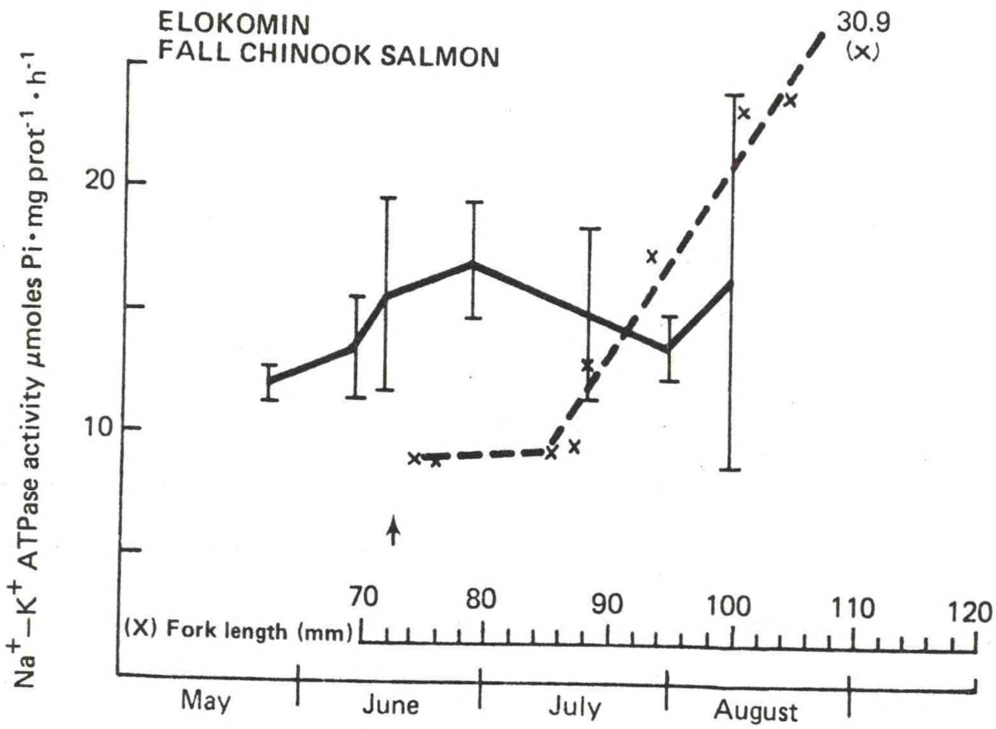


Figure 10 Gill Na^{+}-K^{+} ATPase activities in Elokomin fall chinook salmon.

Kalama Falls Hatchery (SES 18)

Although gill Na^+-K^+ ATPase activities tended to be somewhat higher in 1979 than in 1978, at no time during the sampling period were they elevated sufficiently to indicate a high degree of smoltification in the hatchery (Figure 11).

Two separate releases were made of fish carrying the same tag code, one on 22 June and the other on 12 July. After each of these releases many fish moved rapidly downstream as indicated by captures at Jones Beach (Figure 12). However, others delayed passage through the Jones Beach area for up to 2 months later. Migrants obtained at Jones Beach had much higher gill Na^+-K^+ ATPase activities than fish which had been held at the hatchery for post-release sampling (SES 18, Figure 11).

A plot of fork lengths of captured migrants vs time of passage through the Jones Beach area suggests that those fish which did not migrate immediately grew while in the river (Figure 12). This growth trend leveled off in mid-August. Perhaps high water temperatures and/or limited food supply was responsible for the apparent cessation of growth or perhaps a critical migration size may have been obtained.

SMOLT EVALUATION SUMMARY 18

HATCHERY: KALAMA FALLS SPECIES: FALL CHINOOK STOCK: KALAMA FALLS

DIET: ----- POND #: 18

RELEASE DATE: 22 June 1979
12 July 1979 CODED WIRE TAG: 63-19-57

NUMBER RELEASED: 209,724 BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
1.5	9 Aug	7.9	4 Jun	~7	22 Jun
				7	12 Jul

In seawater:

Number of days:	NO SAMPLING								
Na^+-K^+ ATPase:									
% Mortality:									

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE	RELEASE
Weight (g):	3.0	1.6 - 4.2	1
	4.3	2.9 - 7.4	2
Fork length (mm):	66	55 - 73	1
	70	61 - 83	2
Date:	14 June		1
	12 July		2

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	3 Jul	23 Jul	1 Aug	22 Aug		
Number of fish:	3	11	12	6		
Mean fork length (mm):	72	78	74	88		
Mean Na^+-K^+ ATPase:	16.8	22.3	26.2	30.5		
Mean Plasma T_3:						
Mean Plasma T_4:						

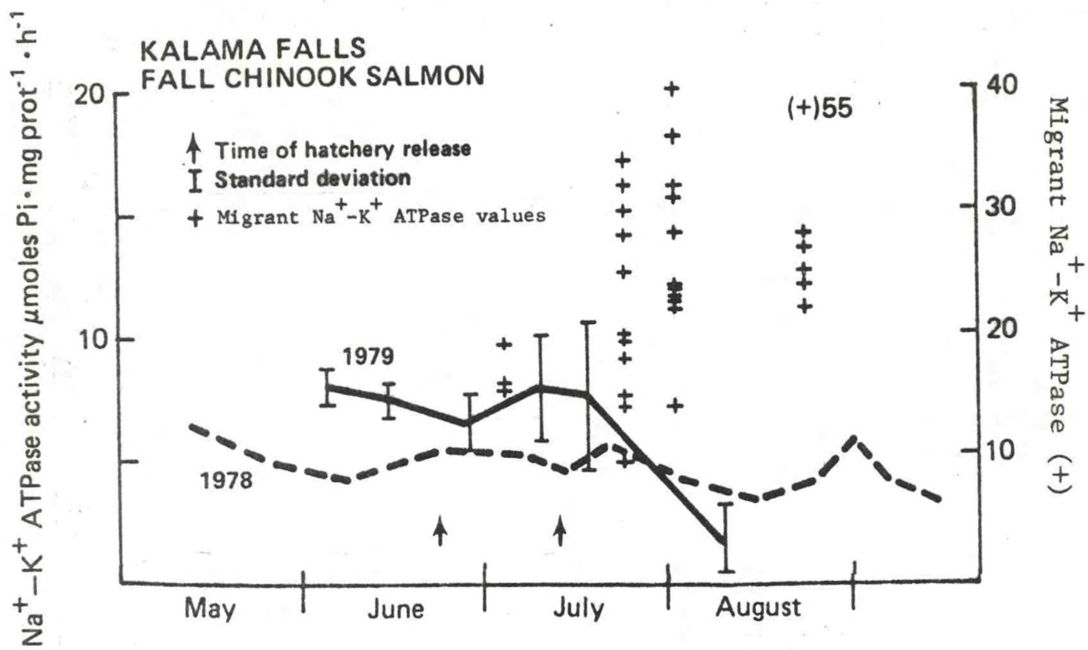


Figure 11 Gill Na^+-K^+ ATPase activities in Kalama Falls fall chinook salmon.

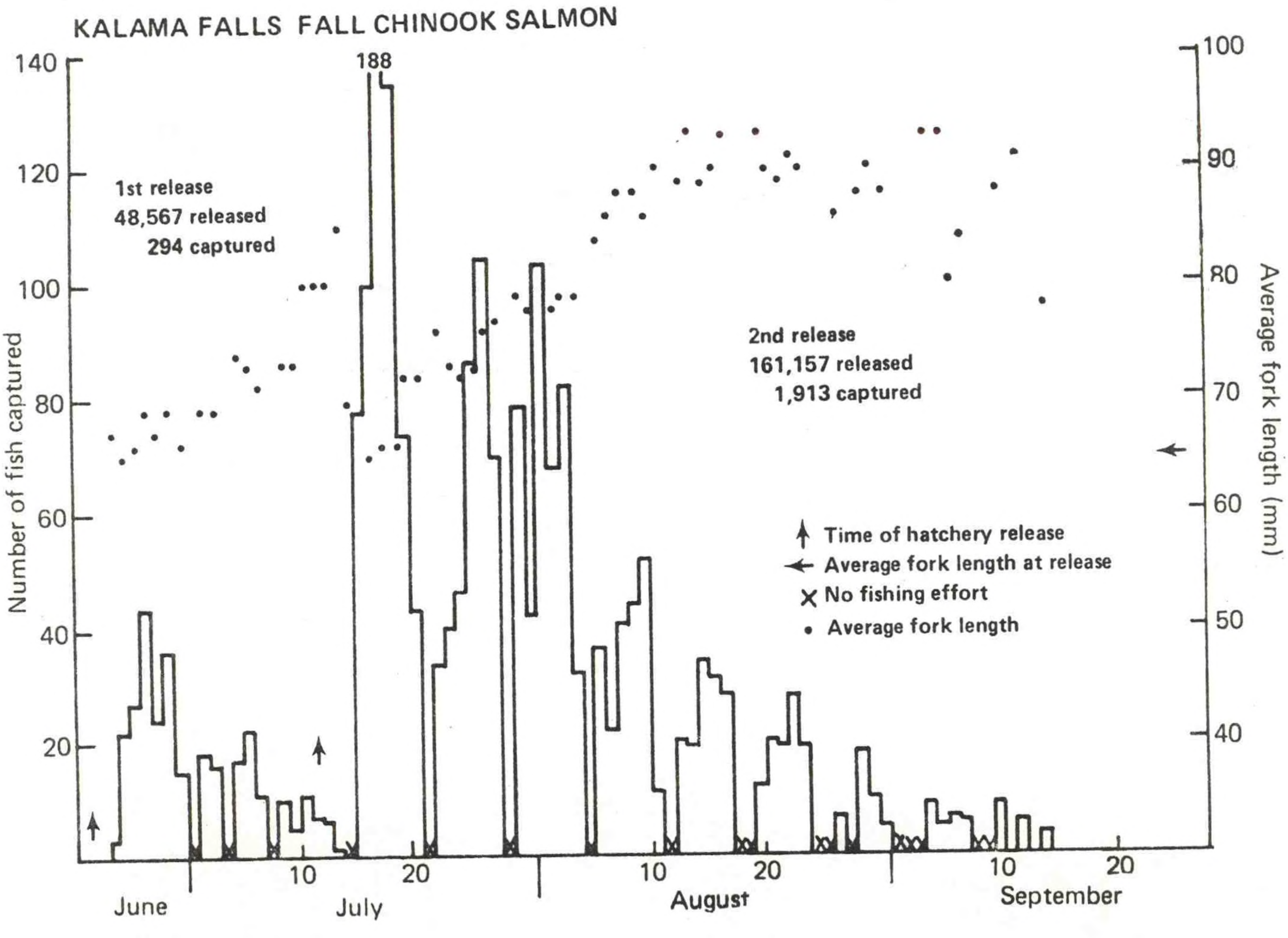


Figure 12 Number of Kalama Falls fall chinook salmon migrants captured at Jones Beach and average fork length of the total number of tagged fish captured on the indicated day.

Toutle Hatchery (SES 19)

Only three samples were taken for gill $Na^{+}-K^{+}$ ATPase activities prior to release (Figure 13), which according to hatchery records was 17 June for both groups (63-19-41 and 63-18-54). However, three fish from 63-19-41 were caught at Jones Beach prior to this release date, which may indicate a recording error. Just as was observed with fall chinook salmon from the Kalama Falls Hatchery, migrants from the Toutle Hatchery increased in size with length of residence in the river. Although the complete data are not presented, this trend is seen in the migrants used for $Na^{+}-K^{+}$ ATPase analyses on 20 June, and 3 and 23 July (SES 19).

Gill $Na^{+}-K^{+}$ ATPase activities also increased in migrants which were caught at the Jones Beach facility at later dates (SES 19). The average length increased from 11.7 mm on 20 June to 23.0 mm on 23 July. This trend seemed to be common among most groups of fall chinook salmon for which data were collected.

SMOLT EVALUATION SUMMARY 19

HATCHERY: TOUTLE

SPECIES: FALL CHINOOK

STOCK: TOUTLE

DIET:

POND #: 25

RELEASE DATE: 17 June 1979

CODED WIRE TAG: 63-18-54 (No. 11,984)
63-19-41 (No. 132,101)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
6.7	22 Jun	7.5	4 June	~ 7	17 Jun

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	3.0	2.1 - 3.9
Fork length (mm):	65	58 - 70
Date:	14 June	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)[a/]

Date captured:	20 Jun	3 Jul	23 Jul			
Number of fish:	3	4	4			
Mean fork length (mm):	70	76	85			
Mean Na^+-K^+ ATPase:	11.7	17.9	23.0			
Mean Plasma T_3:						
Mean Plasma T_4:						

a/ All fish but one (3 July) carried tag 63-19-41.

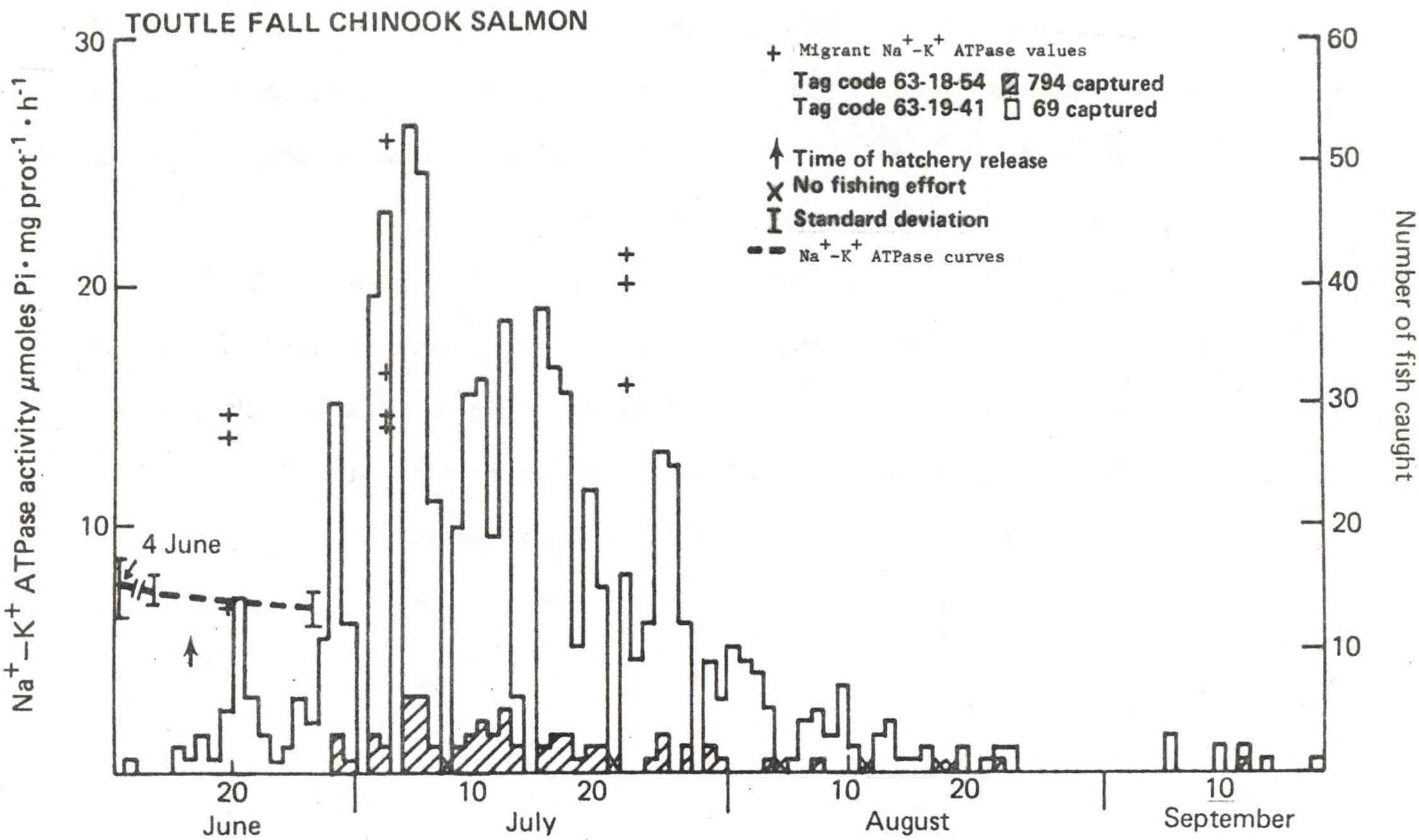


Figure 13 Gill Na^+-K^+ ATPase activities in Toutle fall chinook salmon and numbers of migrants captured at Jones Beach.

Washougal Hatchery (SES 20)

No gill Na^{+}-K^{+} ATPase profile was established for fish released in June. However, capture data and Na^{+}-K^{+} ATPase values of migrants were obtained (Figure 14).

On 12 June, Na^{+}-K^{+} ATPase activities were determined on fish from a pond of fall chinook salmon being held for a fall release (Figure 14). Activity peaked around 30 July followed by a rapid drop which may have been in response to intense medication administered because of disease problems. Fish were receiving 25 ppm formaldehyde by drip method.

Five percent of the fish released on 2 September (fall release) carried coded wire tags, but the codes were the same as used in the spring release. The total fish tagged and released in the fall with tag number 63-19-38 was 6,441, and with tag number 63-19-46 it was 10,214. No fish were recovered in the estuary from the fall release.

SMOLT EVALUATION SUMMARY 20

HATCHERY: WASHOUGAL | SPECIES: FALL CHINOOK | STOCK: WASHOUGAL AND TOUTLE

DIET: | POND #:

RELEASE DATE: 14 June 1979 | CODED WIRE TAG: 63-19-38 (No. 102,819)
63-19-46 (No. 163,012)

NUMBER RELEASED: | BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
10.9	12 Jun	17.8	30 May	~ 10	14 Jun

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	3.9	2.0 - 7.3
Fork length (mm):	73	60 - 91
Date:	12 June	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	20 Jun	3 Jul		20 Jun	3 Jul	1 Aug
Number of fish:	4	3		7	5	1
Mean fork length (mm):	75	78		77	79	99
Mean Na^+-K^+ ATPase:	15.6	20.1		10.7	23.4	20.3
Mean Plasma T_3: Tag:	63-19-38			63-19-46		
Mean Plasma T_4:						

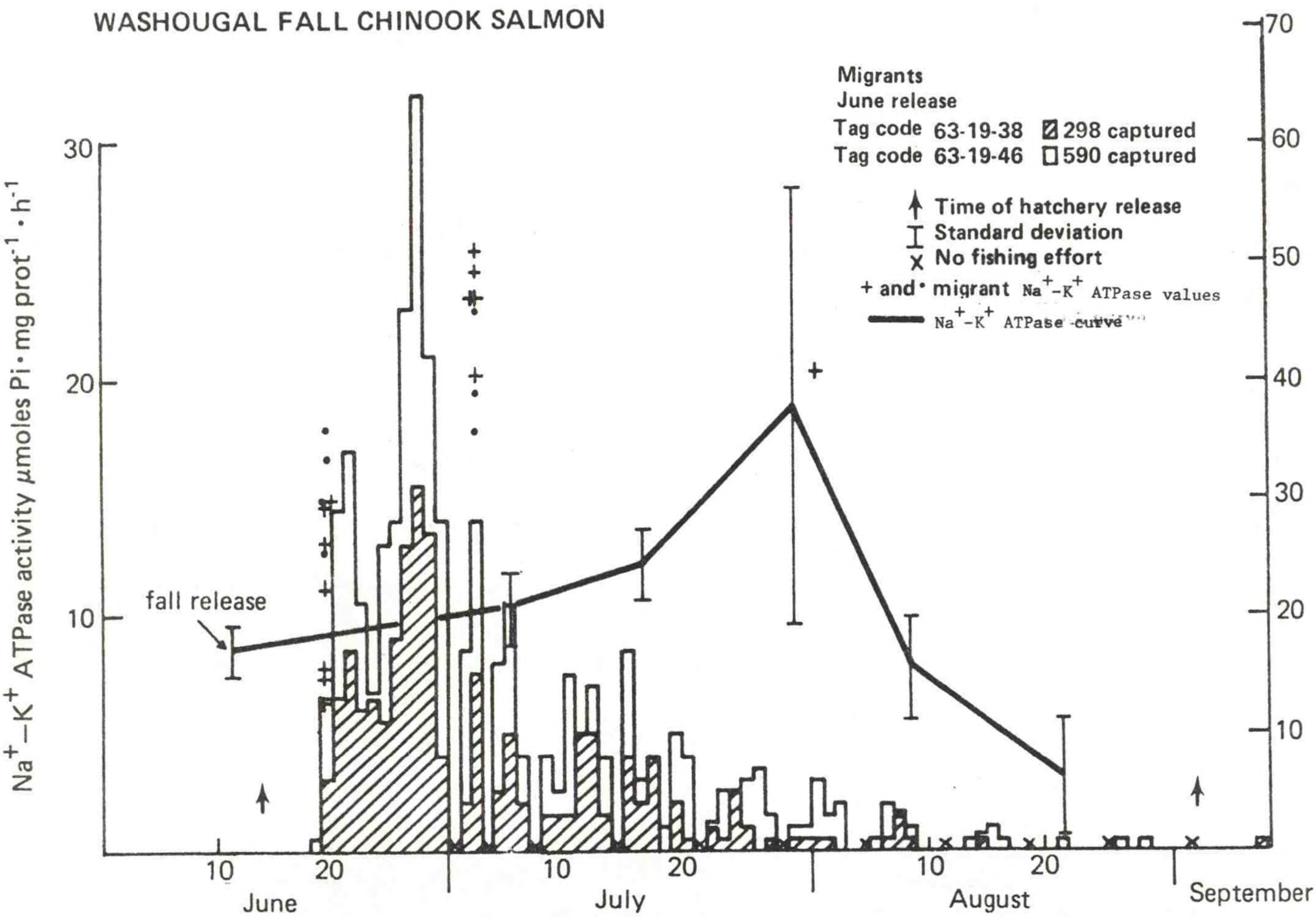


Figure 14 Gill Na^{+}-K^{+} ATPase activities in Washougal fall chinook salmon and numbers of migrants captured at Jones Beach.

Bonneville Hatchery (SES 21, 22)

Fall chinook salmon from Snake River stock were reared for an extended time with part of this population being released on 30 October 1978 and the remainder on 13 March 1979 at age 1+ (SES 21). An initial report on the October release appeared in last year's report. However, a portion of the Na^{+}-K^{+} ATPase curve for 1978 is reproduced in this report with added values to 12 March 1979 (Figure 15). It was concluded in last year's report that some of the fish captured at Jones Beach were reverting to a parr stage as indicated by general appearance (prominent parr marks) and low gill Na^{+}-K^{+} ATPase activities. With this reversion came the possibility of establishing river residence until the spring of 1979, when, in fact, several fish with this tag were caught at Jones Beach. Not only were some of these fish captured but also several from other groups released on 30 October 1978 (e.g.: six of 7-16-56, four of 70-16-58, and four of 7-16-59). Apparently, an unknown number of fish released on 30 October remained in the Columbia River or accessible tributaries over the winter and migrated the following spring (1979). The probability seems high that fish wintering over in the lower Columbia River or its tributaries and going to sea in the spring of the following year would not return to their hatchery of origin. It is interesting that there were no "jack" returns to the hatchery in 1979 of fish carrying tag 7-16-60 (October release), while 66 "jacks" returned with tag 7-16-61 (March release).

Only one sampling for gill Na^{+}-K^{+} ATPase activity was taken on fall chinook salmon released 29 May 1979 (SES 22), and no migrants were available for enzyme determinations. Therefore, no relationships can be made between migratory movements and Na^{+}-K^{+} ATPase activity.

SMOLT EVALUATION SUMMARY 21

HATCHERY: BONNEVILLE	SPECIES: FALL CHINOOK	STOCK: SNAKE RIVER	
DIET: -----	POND #: 13 and 14		
RELEASE DATE: 30 Oct 1978 13 Mar 1979	CODED WIRE TAG: 7-16-60 (No. 51,663) 7-16-61 (No. 33,336)		
NUMBER RELEASED:	BRAND:		

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
10	30 Nov 78	15.4	15 Feb 79	~11.2	13 Mar 79

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE	RELEASE
Weight (g):	19.4	13.2 - 23.9	1
	61.9	28.0 - 109.1	2
Fork length (mm):	121	105 - 130	1
	162	134 - 188	2
Date:	25 Oct 78		1
	12 Mar 79		2

TAGGED FISH CAPTURED AT JONES BEACH:

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^+-K^+ ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 22

HATCHERY: BONNEVILLE

SPECIES: FALL CHINOOK

STOCK: BONNEVILLE "TULES"

DIET: -----

POND #: A10

RELEASE DATE: 29 May 1979

CODED WIRE TAG: 7-16-13 (No. 95,576)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
				8.1	29 May

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	7.1	3.7 - 10.9
Fork length (mm):	86	70 - 100
Date:	29 May	

TAGGED FISH CAPTURED AT JONES BEACH: (total catch)

Date captured:	1 Jun	2 Jun	3 Jun	4 Jun	5 Jun	6 Jun	7-30 Jun
Number of fish:	26	49	14	12	4	11	20
Mean fork length (mm):							
Mean Na^+-K^+ ATPase:							
Mean Plasma T_3:							
Mean Plasma T_4:							

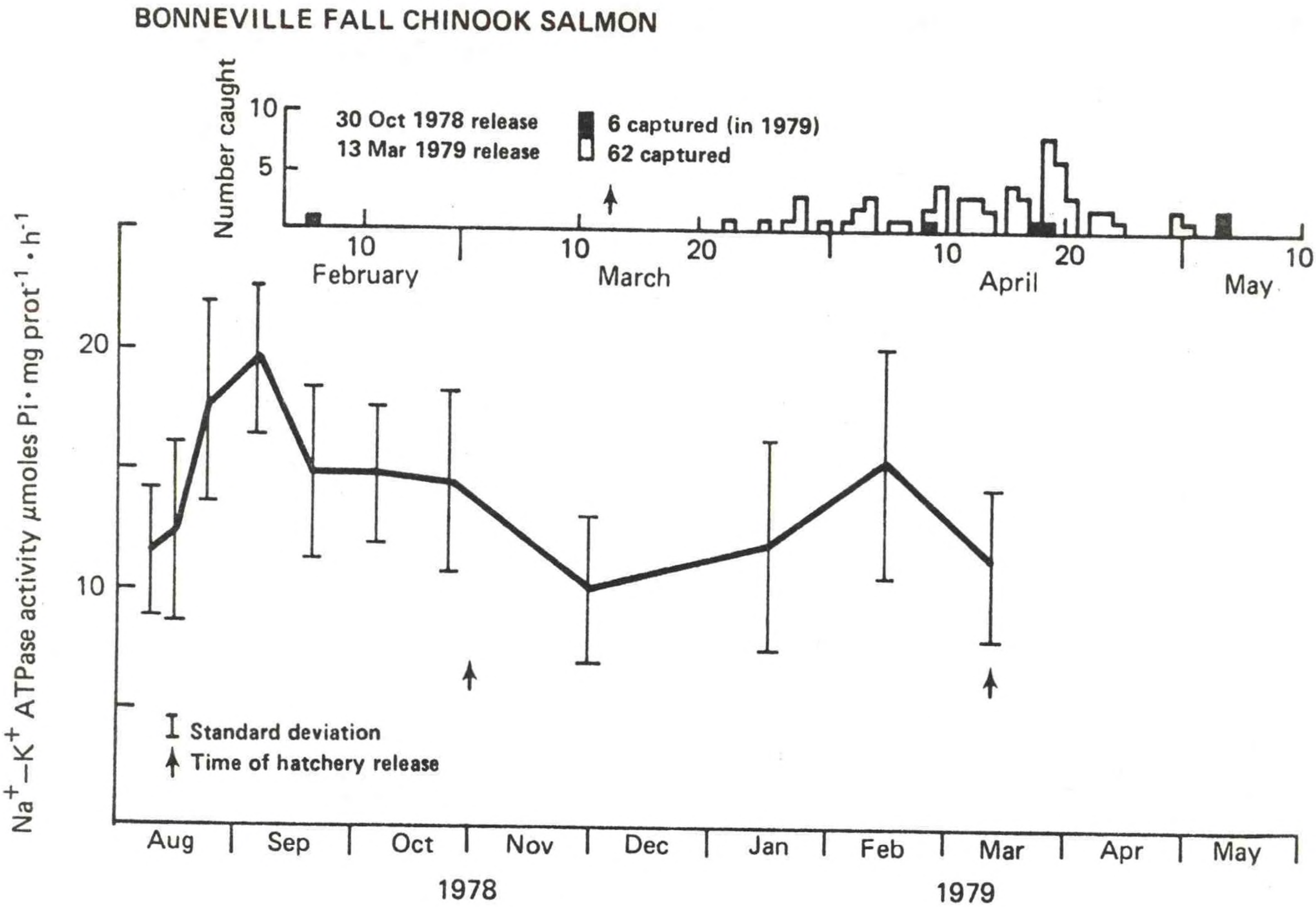


Figure 15 Gill Na^{+}-K^{+} ATPase activities in Bonneville fall chinook salmon (Snake River stock) and numbers of migrants captured at Jones Beach.

Little White Salmon National Fish Hatchery (SES 23)

Determinations of gill Na^+-K^+ ATPase activity were made on Little White Salmon stock of fall chinook salmon (CWT number 5-4-48) from 23 May to release on 22 June (Figure 16, SES 23). At the time of release approximately 500 fish from a second group of fish (CWT number 5-4-49) were brought to and held at the NMFS' laboratory facilities at Willard for sampling through September. Although Na^+-K^+ ATPase activity was not greatly elevated at release in either tagged group, migrants captured at Jones Beach on 3 July had high activities (Figure 16).

SMOLT EVALUATION SUMMARY 23

HATCHERY:	LITTLE WHITE SALMON NFH	SPECIES:	FALL CHINOOK	STOCK:	1-Little White 2-Mixed
DIET:	OMP	POND #:	3		
RELEASE DATE:	22 June 1979	CODED WIRE TAG:	1. 5-4-48 (No. 177,815) 2. 5-4-49 (No. 264,808)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery: (5-4-48)

Low	Date	High	Date	At release	Date
8.1	7 Jun	10.1	20 Jun	~ 10	22 Jun

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	5.1	4.1 - 6.5
Fork length (mm):	78	72 - 84
Date:	20 June (Code 5-4-48)	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	3 Jul			3 Jul	23 Jul	
Number of fish:	3			7	2	
Mean fork length (mm):	81			74	100	
Mean Na^+-K^+ ATPase:	21.7			21.2	15.0	
Mean Plasma T_3: Code:	5-4-48			5-4-49		
Mean Plasma T_4:						

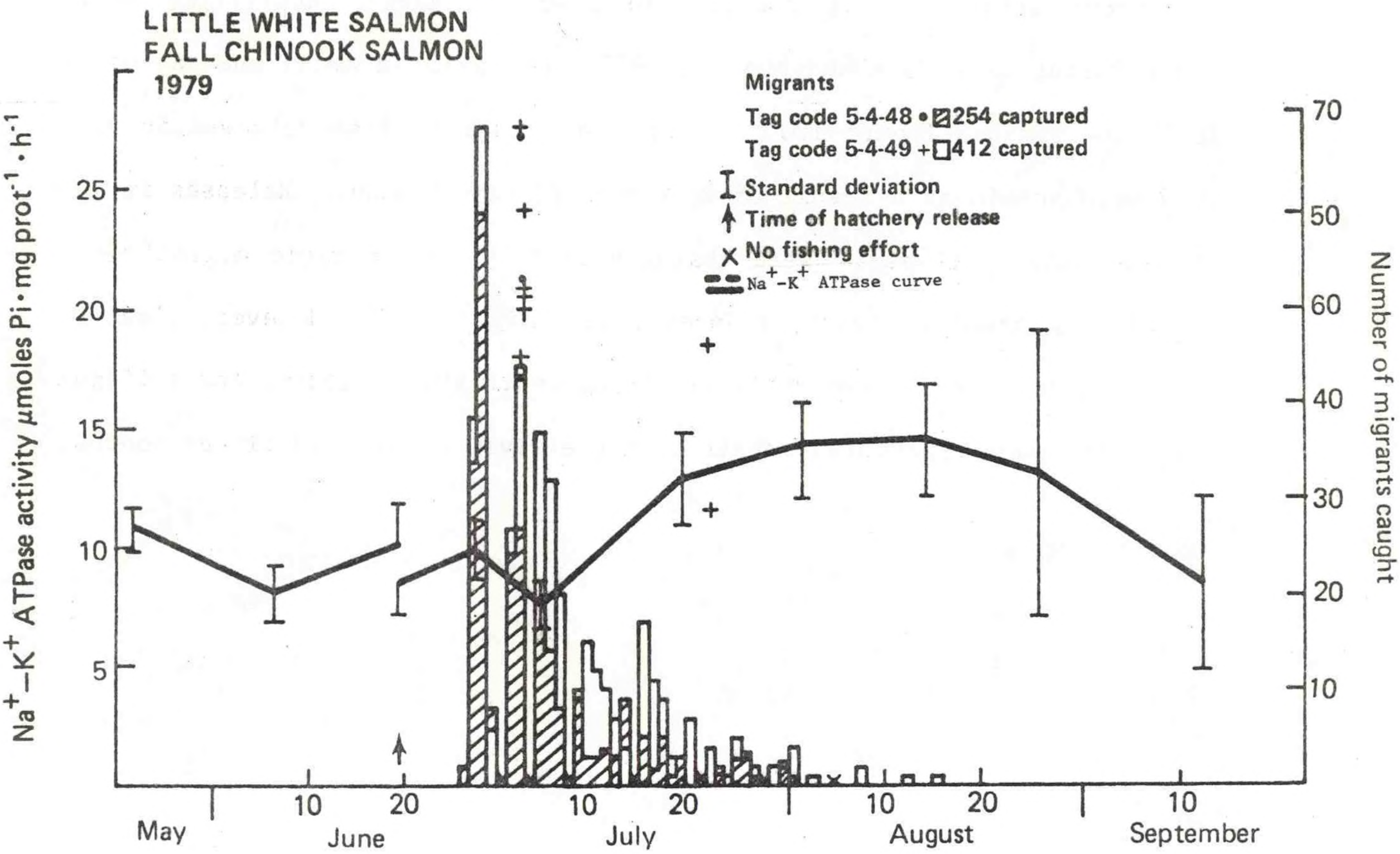


Figure 16 Gill Na^+-K^+ ATPase activities in Little White Salmon fall chinook salmon and numbers of migrants captured at Jones Beach.

Willard National Fish Hatchery (SES 24, 25, 26)

Fall chinook salmon were held beyond the normal release time as 0-age fish in the spring and released in three groups: 12 July 1978 and 14 November 1978, and the following spring on 19 April (1+). Each release had three different tag codes. Gill Na^{+}-K^{+} ATPase activities showed peaks during late July and August, 1978, and again in April and May of the following spring (Figure 17). A high percentage of fish released in April 1979 were anemic as a result of Bacterial Kidney Disease. Releases in July as 0-age and April as 1+ were characterized by rather rapid migrations as judged by migrant recovery at Jones Beach (Figure 17). However, fish from the November release were still migrating up to the following April (Figure 17), since many apparently remained in the river during the winter months.

SMOLT EVALUATION SUMMARY 24

HATCHERY:	WILLARD NFH	SPECIES:	FALL CHINOOK	STOCK:	LITTLE WHITE
DIET:	OMP	POND #:	40		
RELEASE DATE:	12 July 1978	CODED WIRE TAG:	5-3-55, 5-3-56, 5-3-57		
		TOTAL RELEASED:	118,683		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
6.1	29 Jun	10.4	25 Jul	~ 7.5	12 Jul

In seawater:

Number of days:	No sampling									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	5.7	2.9 - 8.4
Fork length (mm):	80	65 - 91
Date:	11 July 1979	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^+-K^+ ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 25

HATCHERY: WILLARD NFH   SPECIES: FALL CHINOOK   STOCK: LITTLE WHITE

DIET: OMP   POND #: 37

RELEASE DATE: 14 November 1978   CODED WIRE TAG: 5-3-52, 5-3-53, 5-3-54

TOTAL RELEASED: 108,218

NUMBER RELEASED: BRAND:

SUMMARY OF GILL $Na^{+}-K^{+}$ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.1	30 Nov	10.4	25 Jul	~5	14 Nov 78

In seawater:

Number of days:	No sampling									
$Na^{+}-K^{+}$ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	14.6	12.2 - 19.6
Fork length (mm):	110	96 - 124
Date:	24 Oct 1978	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean $Na^{+}-K^{+}$ ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 26

HATCHERY: WILLARD NFH   SPECIES: FALL CHINOOK   STOCK: LITTLE WHITE

DIET: OMP   POND #: 12

RELEASE DATE: 19 April 1979   CODED WIRE TAG: 5-3-49, 5-3-50, 5-3-51
TOTAL RELEASED: 95,330

NUMBER RELEASED: BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles $P_i \cdot$ mg protein$^{-1} \cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
4.1	30 Nov	9.3	26 Apr	~ 9	19 Apr

In seawater:

Number of days:	No sampling									
Na^{+}-K^{+} ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	16.6	7.8 - 29.7
Fork length (mm):	11.3	92 - 140
Date:	26 Apr 1979	

TAGGED FISH CAPTURED AT JONES BEACH: (total number captured)

Date captured:	No data					
Number of fish:						
Mean fork length (mm):						
Mean Na^{+}-K^{+} ATPase:						
Mean Plasma T_3:						
Mean Plasma T_4:						

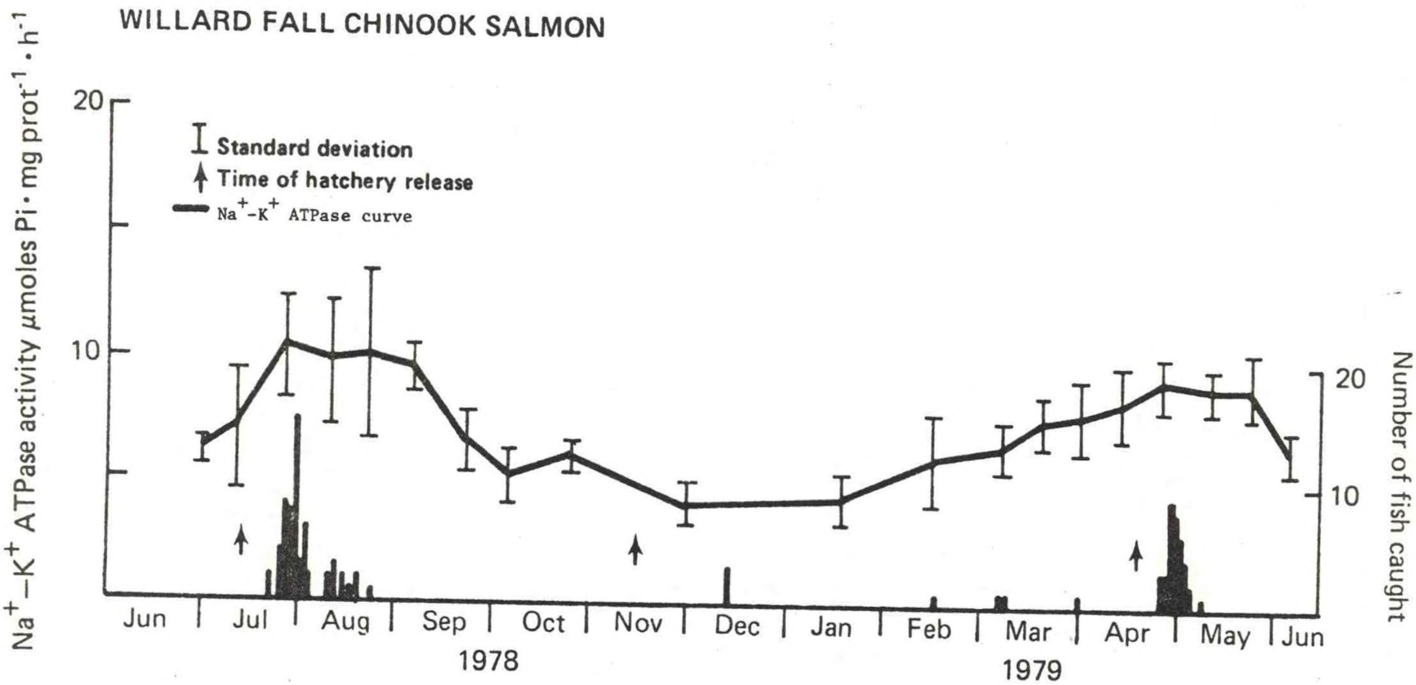


Figure 17 Gill Na^+-K^+ ATPase activities in Willard fall chinook salmon and numbers of migrants captured at Jones Beach.

Spring Creek National Fish Hatchery (SES 27, 28, 29, 30)

The 1979 profile of gill Na^+-K^+ ATPase activities in Spring Creek fall chinook salmon resembled the profile for 1978 with respect to timing of elevations and decrease in activities (Figure 18). However, the July-August increase was more rapid and of greater magnitude in 1979 than in 1978.

Migrations of tagged groups through the Jones Beach area followed the pattern seen in 1978. Migration of fish released in March was characterized by a bi-modal pattern with a surge of fish passing Jones Beach soon after release, followed by a decrease in numbers, and then another surge of migrants in late April and the first of May (Figure 19). Fish from the March, April, and May releases appeared to have cleared the river in early June, with the May release group showing the most rapid migration of these three releases (Figure 19). Fish released in August moved rapidly downstream and were observed at Jones Beach for only a short time (Figure 19).

Tagged fish from the March release moving to the lower river during late April and May were larger than those that migrated immediately following release (Figure 20). Fork lengths of fish caught at Jones Beach during the first half of April were close to the average determined at release. However, later migrating fish were larger, showing growth during the period of residence in the river. It is interesting that migrants from the March release captured at Jones Beach at the same time as migrants from the April release were about the same size, suggesting that growth in the river may have been nearly as great as in the hatchery (Figure 20).

SMOLT EVALUATION SUMMARY 27

HATCHERY:	SPRING CREEK NFH	SPECIES:	FALL CHINOOK	STOCK:	SPRING CREEK
DIET:	Abernathy Dry	POND #:	12, 22, & 25		
RELEASE DATE:	20 March 1979	CODED WIRE TAG:	5-4-46 (No. 245,981)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
7.2	1 Mar	9.9	20 Mar	~ 9.9	20 Mar

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	3.4	2.5 - 4.8
Fork length (mm):	67	58 - 74
Date:	20 Mar	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	19 Apr	3 May	17 May			
Number of fish:	1	2	2			
Mean fork length (mm):	73	75	81			
Mean Na^+-K^+ ATPase:	9.0	15.5	20.3			
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 28

HATCHERY:	SPRING CREEK NFH	SPECIES:	FALL CHINOOK	STOCK:	SPRING CREEK
DIET:	Abernathy Dry	POND #:	29		
RELEASE DATE:	20 Apr 1979	CODED WIRE TAG:	5-4-34 (No. 95,581) 5-4-44 (No. 135,537)		
NUMBER RELEASED:		BRAND:			

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i $\cdot$ mg protein^{-1} $\cdot$ hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
7.5	11 Apr	9.1	23 Mar	~8.6	20 Mar

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	4.3	2.3 - 6.3
Fork length (mm):	75	62 - 85
Date:	20 Apr	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	3 May	17 May				
Number of fish:	4	1				
Mean fork length (mm):	77	85				
Mean Na^+-K^+ ATPase:	21.8	16.4				
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 29

HATCHERY: SPRING CREEK NFH SPECIES: FALL CHINOOK STOCK: SPRING CREEK

DIET: Abernathy Dry POND #: 28

RELEASE DATE: 18 May 1979 CODED WIRE TAG: 5-4-33 (No. 140,948)

NUMBER RELEASED: BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles P_i · mg $protein^{-1}$ · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
11.5	26 Apr	19.6	9 May	~ 14.6	18 May

In seawater:

Number of days:	No samples								
Na^{+}-K^{+} ATPase:									
% Mortality:									

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):		
Fork length (mm):	95	80 - 106
Date:	18 May	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	24 May					
Number of fish:	3					
Mean fork length (mm):	95					
Mean Na^{+}-K^{+} ATPase:	23.8					
Mean Plasma T_3:						
Mean Plasma T_4:						

SMOLT EVALUATION SUMMARY 30

HATCHERY: SPRING CREEK NFH SPECIES: FALL CHINOOK STOCK: SPRING CREEK

DIET: Abernathy Dry POND #: 20

RELEASE DATE: 13 Aug 1979 CODED WIRE TAG: 5-4-45 (No. 55,635)

NUMBER RELEASED: BRAND:

SUMMARY OF GILL Na^+-K^+ ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date
7.6	18 Jun	25.8	26 Jul	~ 23	13 Aug

In seawater:

Number of days:	No samples									
Na^+-K^+ ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	20.9	15.0 - 33.2
Fork length (mm):	121	105 - 139
Date:	10 Aug	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	13 Aug					
Number of fish:	7					
Mean fork length (mm):	124					
Mean Na^+-K^+ ATPase:	44.3					
Mean Plasma T_3:						
Mean Plasma T_4:						

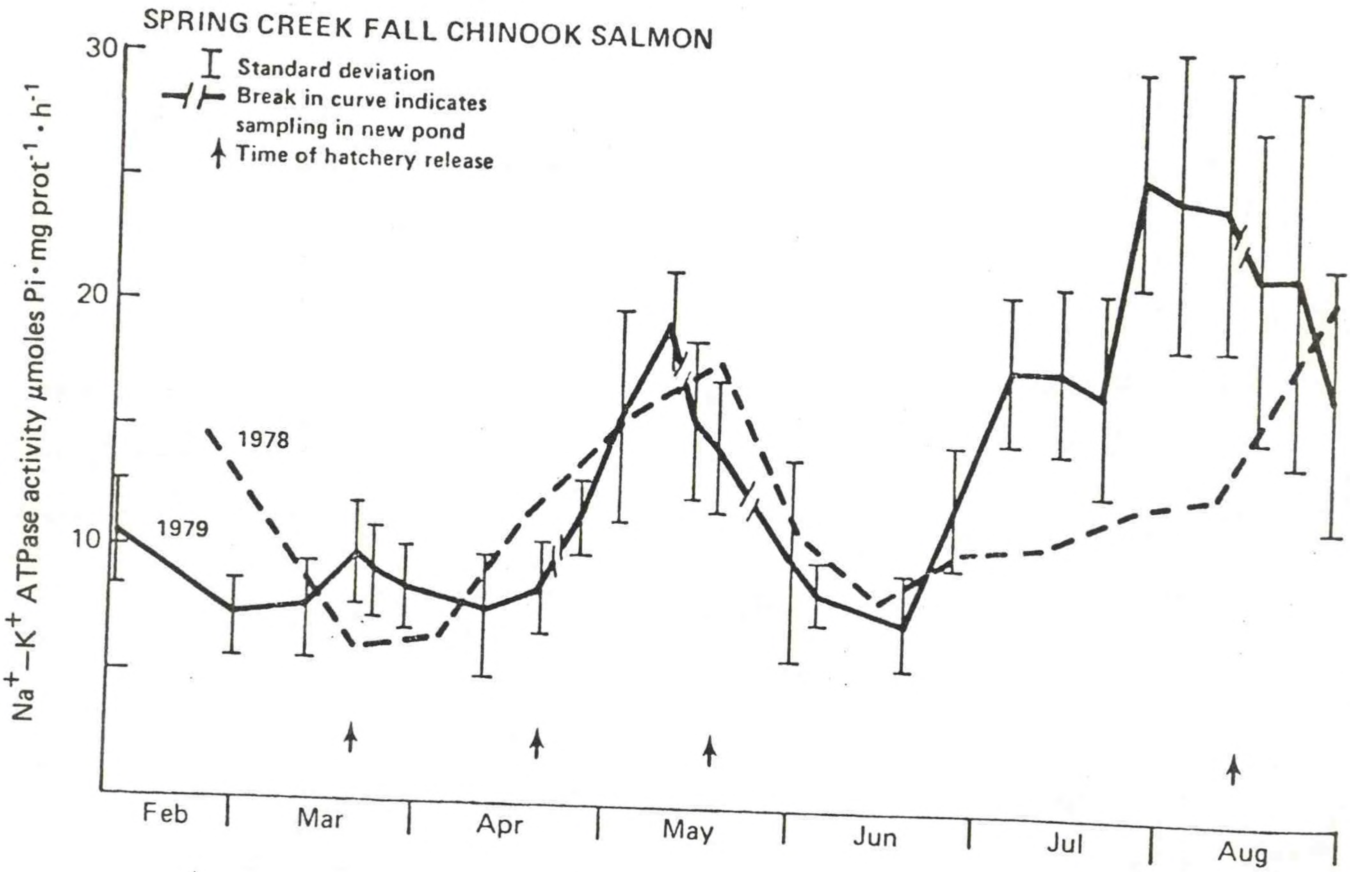


Figure 18 Gill Na^+-K^+ ATPase activities in Spring Creek fall chinook salmon.

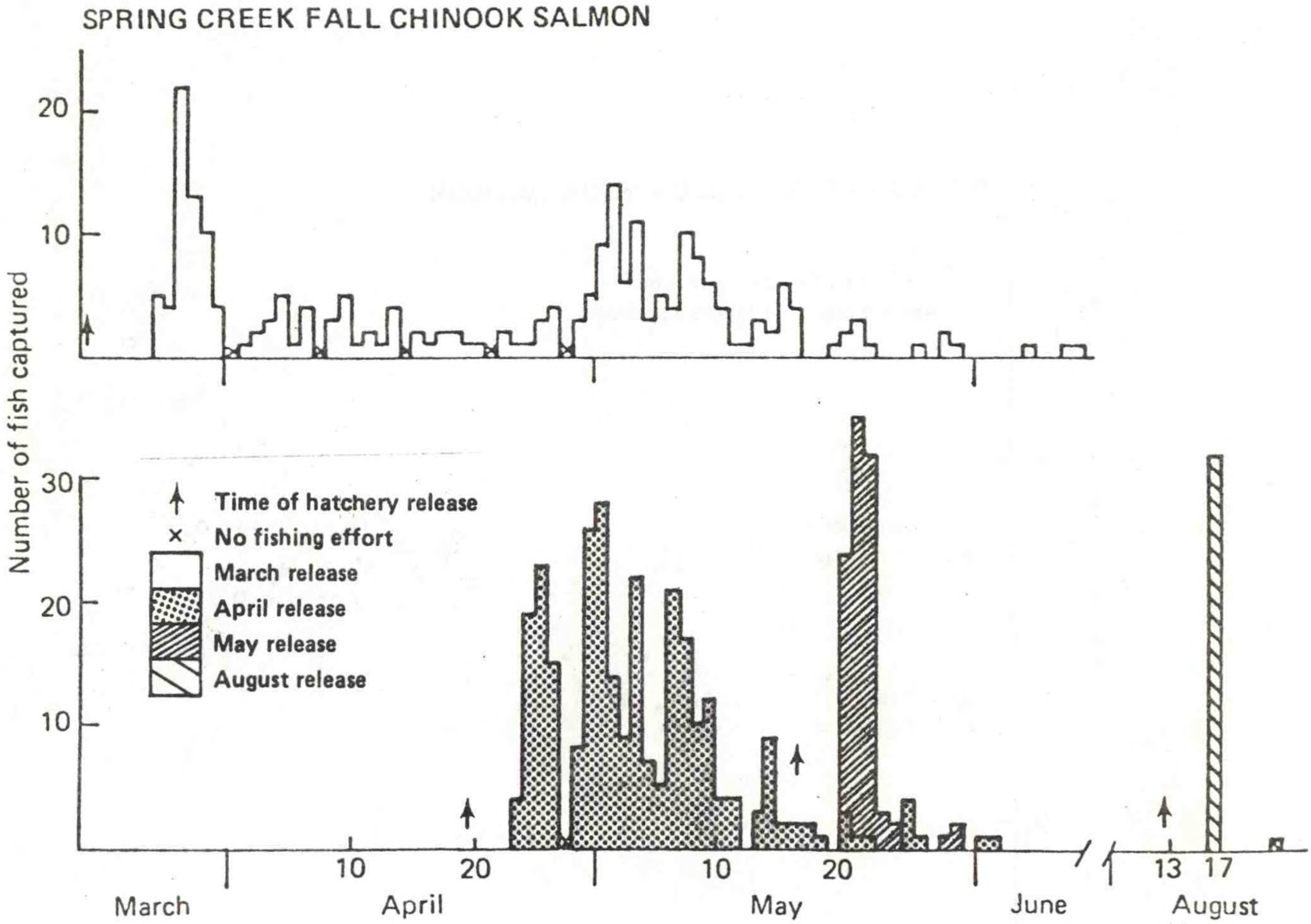


Figure 19 Numbers of Spring Creek fall chinook salmon captured at Jones Beach.

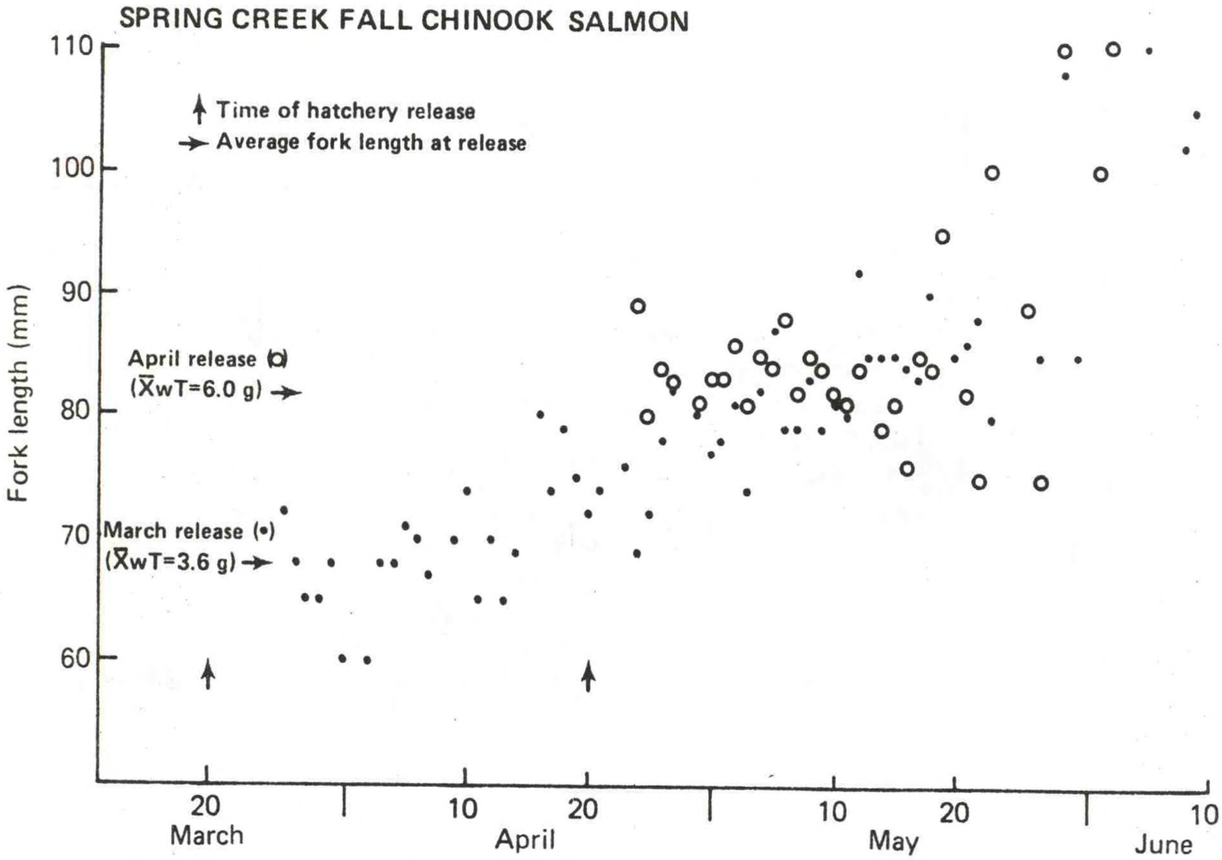


Figure 20 Average fork lengths (mm) of Spring Creek fall chinook salmon migrants. All points are average lengths of the total number of fish caught on the corresponding date (Figure 18).

Spring Creek National Fish Hatchery (Big White) (SES 31)

Fall chinook salmon were tagged and moved from the Spring Creek Hatchery to holding ponds on the Big White Salmon River. Several groups of fish were held in separate pens within one of the ponds. These fish were used in NMFS homing studies. The fish were sampled for Na^+-K^+ ATPase activities and the results plotted (Figure 21). Another group of tagged fish (code 5-4-43) was held in an adjacent pond and released at that site for a contribution study. Data on migrants from this group are also plotted in Figure 21.

Gill Na^+-K^+ ATPase in the homing study fish showed an increase in activity at approximately the same time as in fish held at Spring Creek Hatchery (Figure 18), though the magnitude of that increase was less. Colder water at the Big White Salmon River and slower growth were factors that probably affected the Na-K^+ ATPase activity.

SMOLT EVALUATION SUMMARY 31

HATCHERY: SPRING CREEK (BIG WHITE)

SPECIES: FALL CHINOOK

STOCK: SPRING CREEK

DIET: Abernathy Dry

POND #:

RELEASE DATE: 21 May 1979

CODED WIRE TAG: 5-4-43 (No. 141,393)

NUMBER RELEASED:

BRAND:

SUMMARY OF GILL Na^{+}-K^{+} ATPase (μmoles P_i · mg protein^{-1} · hr^{-1})

At hatchery:

Low	Date	High	Date	At release	Date

In seawater:

Number of days:	No sampling									
Na^{+}-K^{+} ATPase:										
% Mortality:										

SIZE OF FISH SAMPLED FOR ATPase NEAR TIME OF HATCHERY RELEASE:

	AVERAGE	RANGE
Weight (g):	17.5	
Fork length (mm):		
Date:	21 May	

TAGGED FISH CAPTURED AT JONES BEACH: (only those used for analyses)

Date captured:	31 May					
Number of fish:	6					
Mean fork length (mm):	85					
Mean Na^{+}-K^{+} ATPase:	20.1					
Mean Plasma T_3:						
Mean Plasma T_4:						

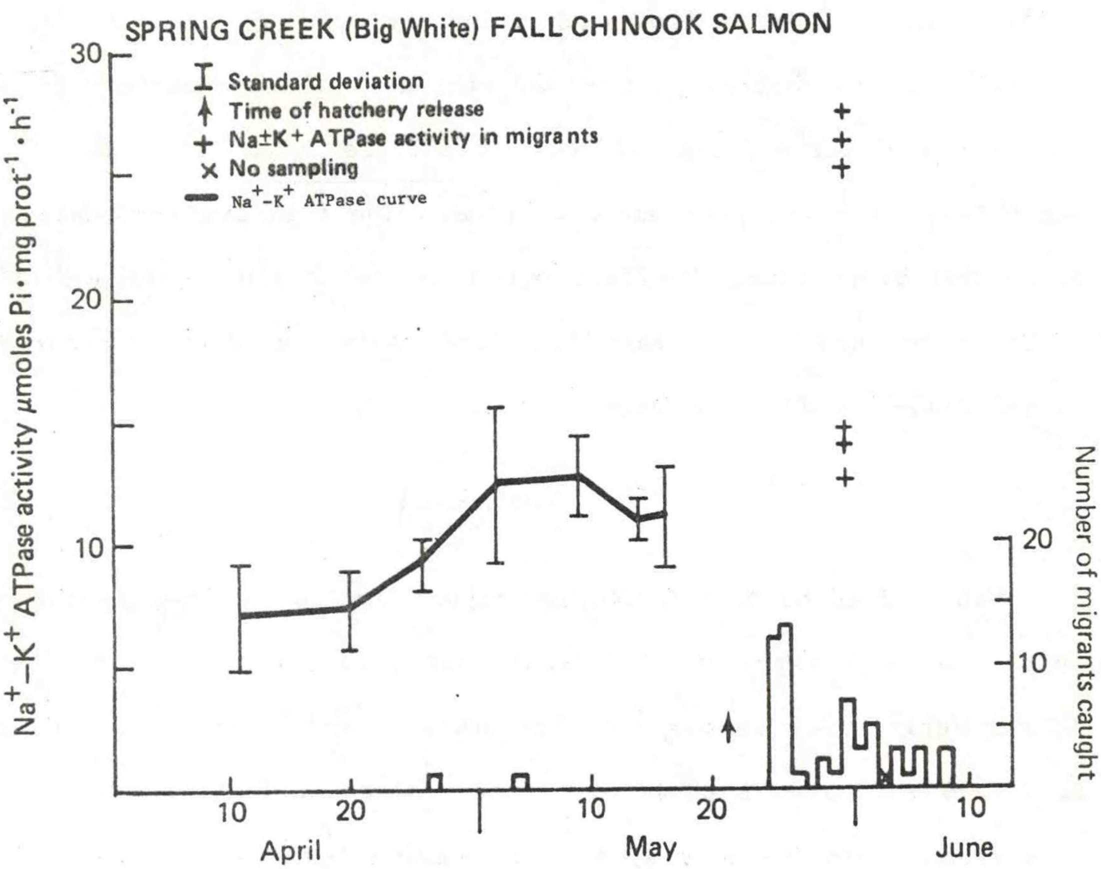


Figure 21 Gill Na^{+}-K^{+} ATPase activities in Spring Creek (Big White) fall chinook salmon and numbers of migrants caught at Jones Beach. A profile of Na^{+}-K^{+} ATPase activities is shown for salmon used in homing studies. Numbers of captured migrants and Na^{+}-K^{+} ATPase activities in migrating fish are shown for a separate group released at the holding site.

SUMMARY AND CONCLUSIONS

Steelhead

Results of gill Na^{+}-K^{+} ATPase assays in steelhead reared at the Tucannon Hatchery were similar in 1978 and 1979 (Figure 1), showing a strong peak in early May accompanied by good development of silvery coloration. In contrast, steelhead reared at Chelan Hatchery (Figure 1), though much larger, failed to demonstrate high gill Na^{+}-K^{+} ATPase activity at the expected smolting time. The fish remained dark and many males were precocious. The fact that water temperatures reached 13°C (54 - 55°F) at the hatchery in late April and early May probably contributed to minimal NA^{+}-K^{+} ATPase increase.

Coho Salmon

Coho salmon held in hatcheries beyond the normal smolting period (late April and May) experienced decreases in previously elevated gill Na^{+}-K^{+} ATPase activities, lost silvery coloration, and began to show prominent parr marks. This was observed in coho salmon at four separate hatcheries (Big Creek, Cascade, Toutle, and Washougal; Figures 2 - 6) where releases were made in May, June, and July. Although fish released in June and July were in a parred stage, as judged by coloration and Na^{+}-K^{+} ATPase activities, migrants soon appeared in the estuary. All captured migrants tested, however, had elevated Na^{+}-K^{+} ATPase activities, were beginning to lose parr marks, and were becoming more silvery. Gill Na^{+}-K^{+} ATPase activities increased with length of time from release, suggesting an active re-smoltification. Thus, coho salmon which had undergone smoltification in hatchery ponds apparently reverted to parr when not released. However, re-smoltification readily occurred upon release by the first week in July and fish then actually migrated more rapidly than those released in May in spite of lower river flow.

Spring Chinook Salmon

Salmon migrating from the Leavenworth Hatchery to the estuary had very high gill Na^+-K^+ ATPase activities. Some individuals had higher activities than others of the same group which had been transferred from the hatchery to Manchester and held in seawater for 6 months (Figure 8). This observation suggests that the "sodium pump" activity in gills of fish migrating downstream for a considerable distance can be fully functional by the time seawater is reached, and that little physiological adjustment is needed for this particular aspect of seawater acclimation.

Fall Chinook Salmon

Some hatchery populations of fall chinook salmon may show no physiological signs of smoltification (low gill Na^+-K^+ ATPase activity, visible parr marks, etc.) yet when released into a river, a certain percentage of this population is capable of undergoing transformation to smolts and migrating rather quickly downstream. The migrants develop elevated levels of gill Na^+-K^+ ATPase activity and silvery coloration typical of smolts. Others of the same population remain in the river and may delay migration up to several weeks. Fish released from the Kalama Falls Hatchery (Figures 11 and 12) were examples of this kind of behavior as were fish released in March from Spring Creek Hatchery (Figure 18). Generally, a higher percentage of populations of fall chinook salmon which have elevated gill Na^+-K^+ ATPase activities migrate rapidly downstream and remain less time in the river, as for example, the May release from Spring Creek (Figures 18 and 19).

Fall chinook salmon held for delayed fall releases migrated well in August from Spring Creek Hatchery (Figures 18, 19; high Na^{+}-K^{+} ATPase) but poorly from Bonneville and Willard Hatcheries when released in October and November, respectively (Figures 15 and 17; low Na^{+}-K^{+} ATPase). Both Bonneville and Willard groups had low gill Na^{+}-K^{+} ATPase activities when released and when individuals were subsequently picked up at Jones Beach in April and May of the following spring. It seems probable that fish which hold over and do not migrate to sea directly from the streams in which they were liberated may not imprint on home waters, but rather on waters in which they smolt and begin active seaward movement. If this is true then many surviving holdovers may not return to their hatchery of origin.

It is becoming increasingly evident that growth rate, water temperature, and other rearing conditions greatly influence the smoltification process in fall chinook salmon, and at the present time the relationships among these parameters are not well understood.

ACKNOWLEDGMENTS

Special thanks to Earl Dawley and personnel at the NMFS' Clatskanie Field Station for time and effort spent in helping collect gill samples from migrating fish and for supplying information on catch dates and numbers caught. The unhesitating cooperation by many individuals in state and federal fishery agencies and hatchery managers and personnel is most gratefully acknowledged as essential to the success of the study.

REFERENCES

Zaugg, W. S., and L. R. McLain.
1976. Influence of water temperature on gill sodium, potassium stimulated ATPase activity in juvenile coho salmon (Oncorhynchus kisutch). Comp. Biochem. Physiol. 54A:419-421.

Zaugg, W. S.
1979. A study to assess status of smoltification and fitness for ocean survival of chinook, coho and steelhead, Proj. Rep. 817, Pacific Northwest Regional Commission. Appendix A, 46 pp.

APPENDIX B

SEAWATER ADAPTATION OF COHO SALMON, SPRING AND FALL CHINOOK SALMON, AND STEELHEAD

by

Earl F. Prentice

F. William Waknitz

and Kurt X. Gores

September 1980

INTRODUCTION

During the FY 1979-80 study 42 groups of fish from 17 state and federal hatcheries were evaluated in seawater (Table 1, Figures 1 and 2). The objectives of this phase of study were to determine seawater adaptation by monitoring growth, mortality, disease, and reversion to parr.

METHODS AND MATERIALS

Appendix B in the FY 1978-79 report discussed in detail the methods and materials used in the study. In 1979-80 several minor changes were made in the method of study. After vaccination, fish remained in fresh water from 1-4 days before transfer to seawater. Also, the sample size of coho and spring chinook salmon and steelhead tested in seawater was reduced from 300 to 200 fish which were held in a single net-pen rather than two separate pens. Fall chinook salmon, because of their size, were held as in 1978.

RESULTS AND DISCUSSION

Seawater evaluation of the various selected test groups (Table 1) started in October 1978 and extended to November 1979. During this interval, environmental data at Clam Bay were compiled daily. At no time did the values of salinity, dissolved oxygen, or water temperature vary from accepted limits for the fish being evaluated (Figure 3).

Detailed disease profiles are described in Appendix D; however, a summary of seawater mortality and disease follows (Table 2).

Vibrio anguillarum Strains 775 and 1669 were the most prevalent pathogens isolated as in the 1978 study period. Bacterial kidney disease (BKD) was also isolated from a number of test groups, however, the incidence of this disease was not as common as vibriosis. Osmoregulatory dysfunction, though not a disease, was included in the seawater profile

Table 1.--Chinook and coho salmon and steelhead test groups for 1979 smoltification and seawater adaptability study.

Hatchery	Stock	Species	Agency	Brood year	Reason for selection	Date of transfer to Manchester month/day/year	Date of sea-water entry month/day/year	Number of replicates
Kalama Falls	Kalama Falls	Fall chinook	WDF[1/]	1978	OII study[6/]-tagged fish	071679	071979	2
Toutle	Green River	Fall chinook	WDF	1978	OII study-tagged fish	062279	062779	1
Bonneville	Snake River	Fall chinook	ODFW[2/]	1977	Age 1+ -tagged fish	031579	032079	2
Bonneville	Bonneville	Fall chinook	ODFW	1978	OII study-estuary[7/]-tagged fish	052979	053179	2
Little White Salmon	Little White Salmon	Fall chinook	USFWS[3/]	1978	OII study-estuary-tagged fish	062279	062779	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	032079	032279	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	041979	042179	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	051879	052279	2
Spring Creek	Spring Creek	Fall chinook	USFWS	1978	OII study-serial release-tagged fish	081079	081479	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	071078	071278	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	103078	110178	2
Willard	Little White Salmon	Fall chinook	USFWS	1977	Serial release-age 1+ -tagged fish	041979	042179	2
Big White Salmon	Spring Creek	Fall chinook	USFWS	1978	OII study-estuary-NMFS homing study-tagged fish	051879	052279	1
Elokomin	Elokomin	Fall chinook	WDF	1978	OII study-tagged fish	061379	061579	2
Washougal	Washougal/Toutle	Fall chinook	WDF	1978	OII study-estuary-tagged fish	061379	061579	2
Carson	Carson	Spring Chinook	USFWS	1977	NMFS homing study-tagged fish	050179	050379	1
Leavenworth	Carson	Spring Chinook	USFWS	1977	Tagged fish	042579	042779	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	050779	050979	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	060779	061079	1
Washougal	Cowlitz	Coho	WDF	1977	Serial release-tagged fish	070679	071079	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	050779	050979	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	060779	061079	1
Big Creek	Big Creek	Coho	ODFW	1977	Serial release-tagged fish	070679	071079	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	050779	050979	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	060779	061079	1
Cascade	Sandy	Coho	ODFW	1977	Serial release-tagged fish	070679	071079	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	050779	050979	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	061379	061679	1
Toutle	Green River	Coho	WDF	1977	Serial release-tagged fish	070679	071079	1
Toutle	Green River	Coho	NMFS[4/]	1976	Baseline serial entry 1	031579	032079	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 2	032979	040379	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 3	041379	041779	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 4	042779	050179	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 5	051179	051579	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 6	052579	053079	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 7	060879	061279	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 8	072079	072479	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 9	081679	082179	1
Toutle	Green River	Coho	NMFS	1976	Baseline serial entry 10	091679	091879	1
Tucannon	Skamania	Steelhead	WDG[5/]	1978	NMFS homing study-tagged fish	051479	051679	1
Chelan	Chelan	Steelhead	WDG	1978	NMFS homing study-tagged fish	042579	042779	1
Wells	Wells	Steelhead	WDG	1978	NMFS homing study-tagged fish	051079	051279	1

1/ Washington Department of Fisheries
2/ Oregon Department of Fish and Wildlife
3/ US Fish and Wildlife Service
4/ National Marine Fisheries Service
5/ Washington Department of Game
6/ NMFS Operational Improvement Investigations
7/ NMFS Estuary Migrant Capture Evaluation study

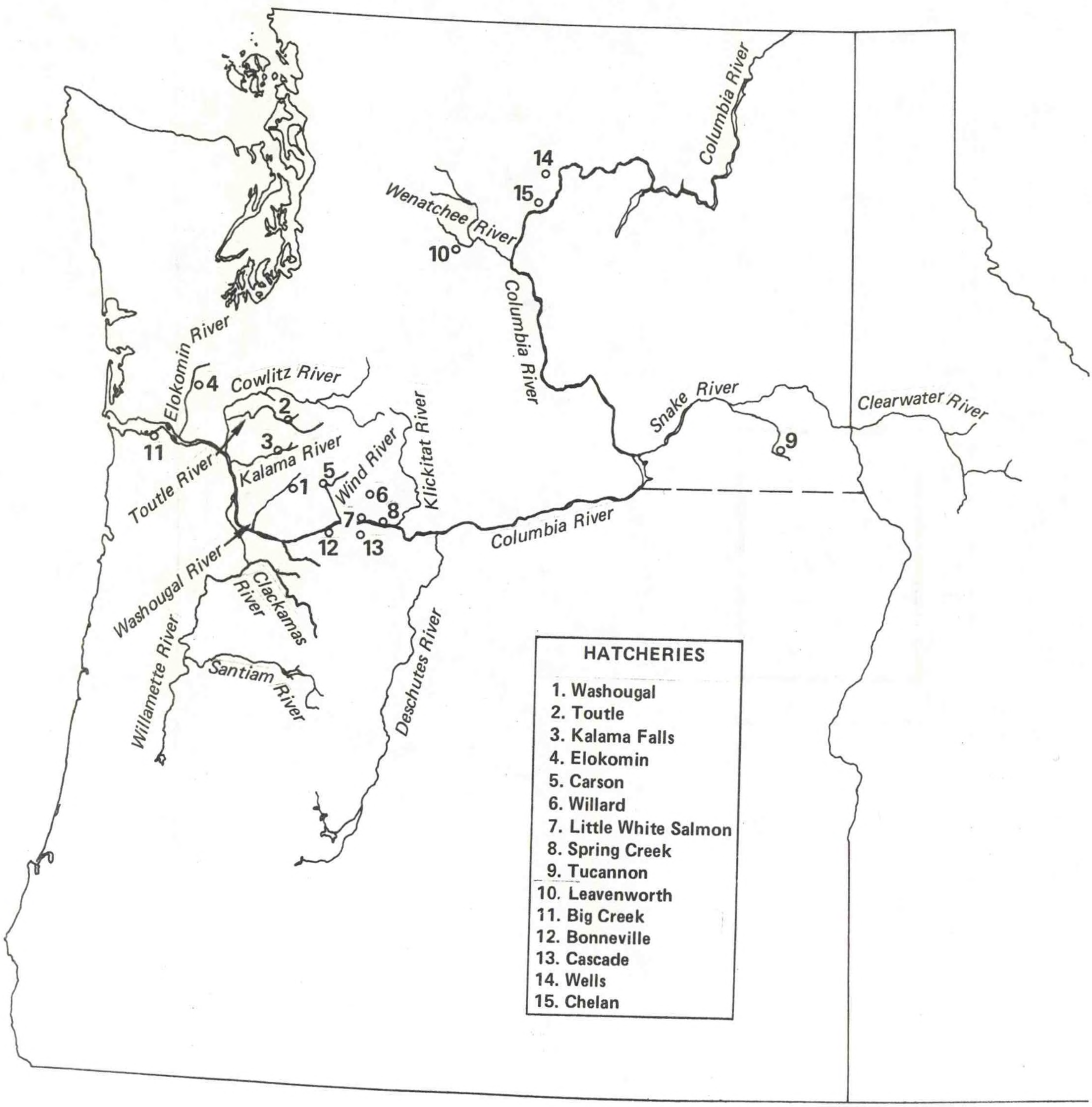


Figure 1.--Location of cooperating hatcheries.

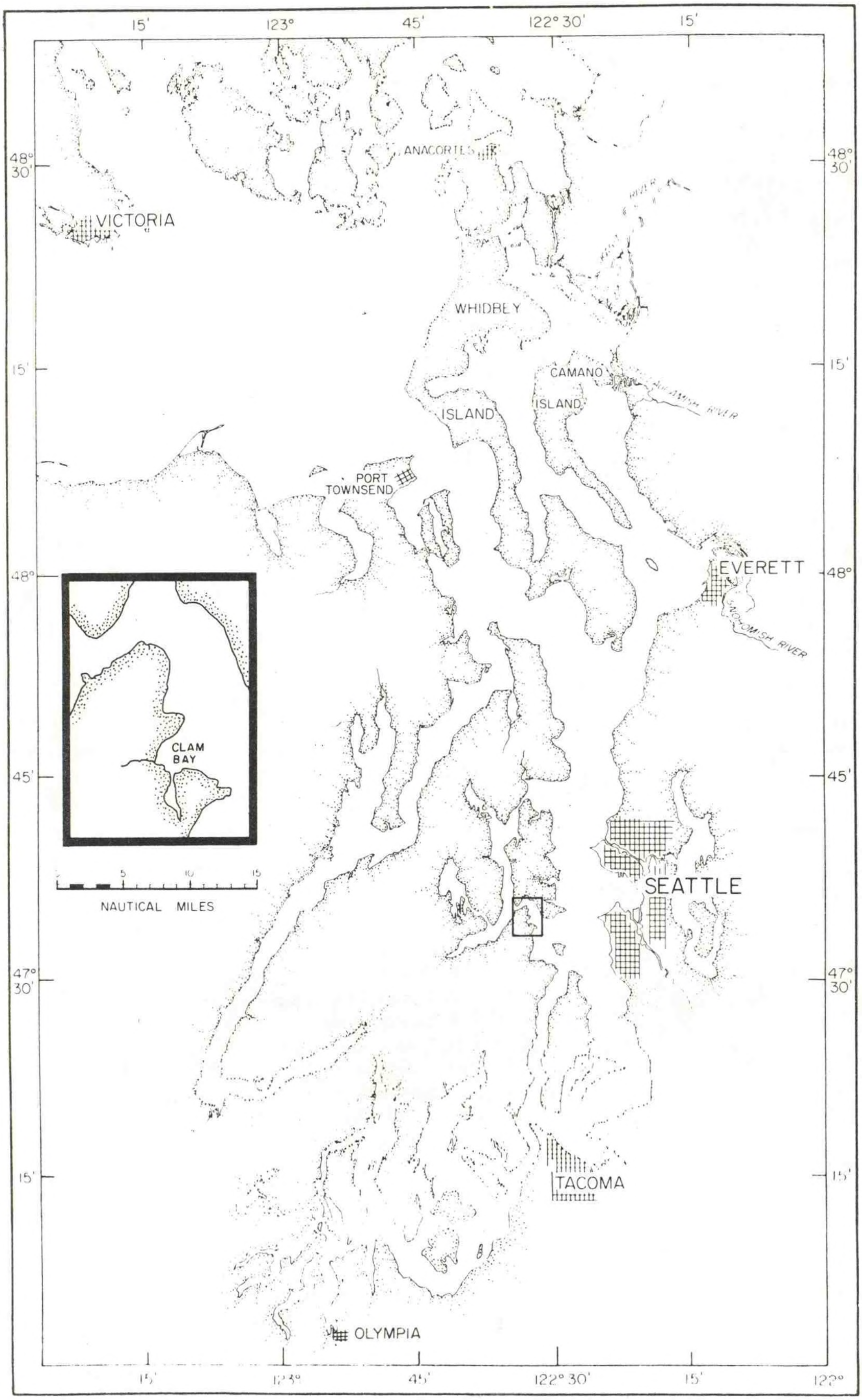


Figure 2.--Location of Manchester seawater test facilities.

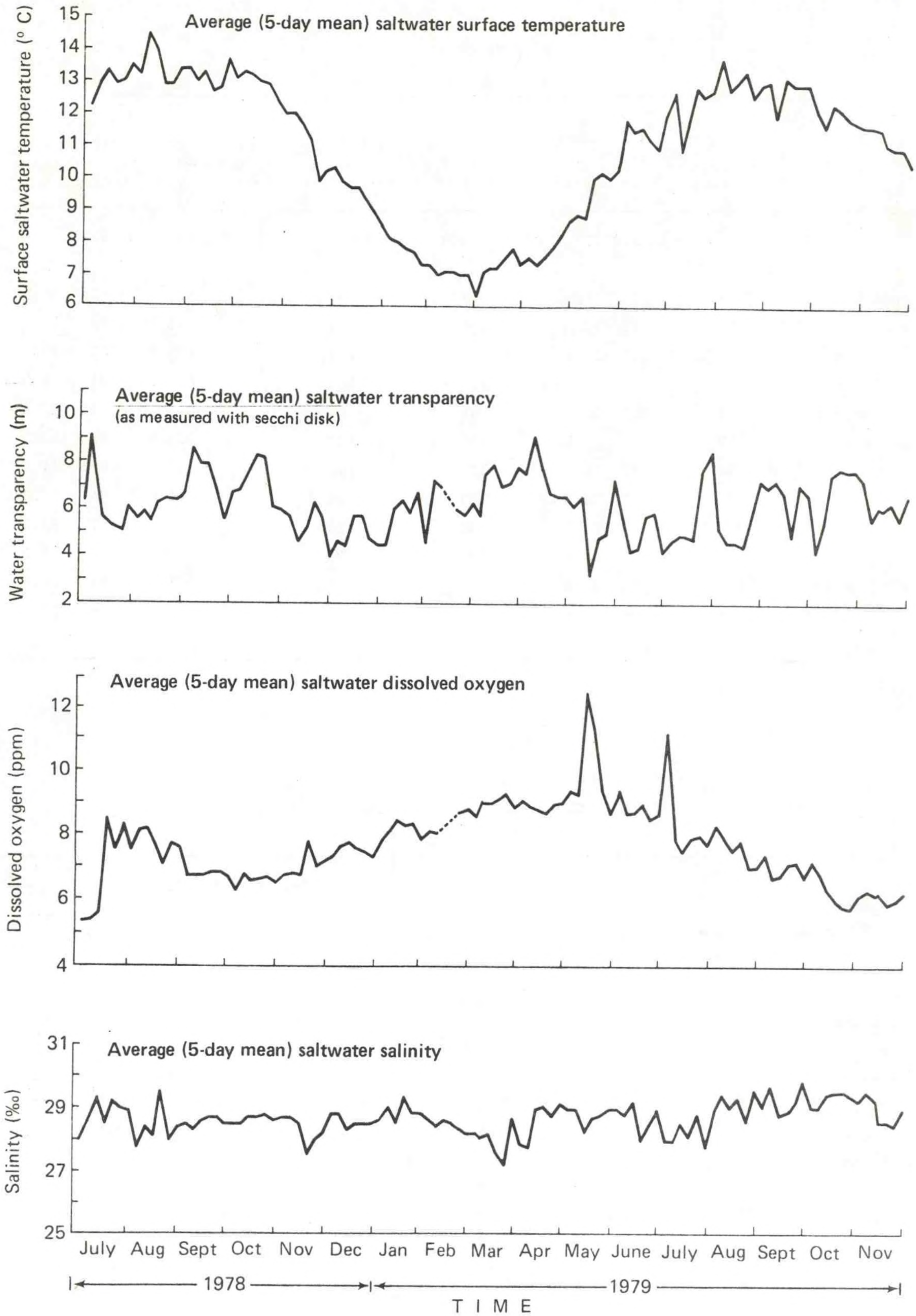


Figure 3.--Environmental data at Clam Bay, Washington, for the period of July, 1978 to November, 1979.

Table 2.-- Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Coho											
Big Creek Group 1	200	112	56.0	88	81	7	3.5	61	30.5	20	10.0
Big Creek Group 2	200	64	32.0	136	41	95	47.5	26	13.0	15	7.5
Big Creek Group 3	200	77	38.5	123	119	4	1.3	92	30.7	27	9.0
Cascade Group 1	200	82	41.0	118	106	12	6.0	91	45.5	15	7.5
Cascade Group 2	200	104	52.0	96	95	1	0.5	75	37.5	20	10.0
Cascade Group 3	200	70	35.0	130	123	7	3.5	100	33.3	23	7.7
Toutle Group 1	200	92	46.0	108	110	2 a/	1.0	89	44.5	21	10.5
Toutle Group 2	200	72	36.0	128	121	7	3.5	94	47.0	27	13.5
Toutle Group 3	200	68	34.0	132	126	6	3.0	107	53.5	19	9.5
Washougal Group 1	200	66	33.0	134	126	8	4.0	98	49.0	28	14.0
Washougal Group 2	200	77	38.5	123	116	7	3.5	97	48.5	19	9.5
Washougal Group 3	200	64	32.0	136	131	5	2.5	104	52.0	27	13.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD b/	775 c/	1669 c/	7244 c/	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM d/	Aero e/ Liq	Osmo f/ Dys	Furun g/	Other
Coho															
Big Creek Group 1	6	0	11	1	0	0	0	0	0	2	0	0	0	0	0
Big Creek Group 2	3	1	9	2	0	0	0	0	0	0	0	0	0	0	0
Big Creek Group 3	7	0	13	6	0	0	0	0	1	0	0	0	0	0	0
Cascade Group 1	6	2	2	4	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 2	10	1	5	3	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 3	10	0	11	2	0	0	0	0	0	0	0	0	0	0	0
Toutle Group 1	12	0	5	3	0	0	0	0	0	1	0	0	0	0	0
Toutle Group 2	8	1	8	6	0	0	0	1	0	3	0	0	0	0	0
Toutle Group 3	12	0	6	1	0	0	0	0	0	0	0	0	0	0	0
Washougal Group 1	13	1	7	5	0	0	0	0	0	1	0	0	0	0	1
Washougal Group 2	8	1	9	0	0	0	0	0	0	0	0	0	0	0	1
Washougal Group 3	11	0	9	7	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 2.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Baseline Coho (Toutle Stock)											
Serial Entry 1	150	47	31.3	103	103	0	0.0	88	58.7	15	10.0
Serial Entry 2	150	33	22.0	117	116	1	0.7	90	60.0	26	17.3
Serial Entry 3	151	51	33.8	100	98	2	1.3	76	50.7	22	14.7
Serial Entry 4	150	56	37.3	94	97	3 a/	2.0	77	51.3	20	13.3
Serial Entry 5	149	62	41.6	88	84	4	2.7	65	43.6	19	12.8
Serial Entry 6	150	57	38.0	93	88	5	3.3	66	44.0	22	14.7
Serial Entry 7	150	63	42.0	87	75	12	8.0	61	40.7	14	9.3
Serial Entry 8	15C	85	56.7	65	72	7 a/	4.7	54	36.0	18	12.0
Serial Entry 9	150	86	57.3	64	61	3	2.0	50	33.3	11	7.3
Serial Entry 10	150	139	92.7	11	8	3	2.0	7	4.7	1	0.7

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD b/	775 c/	1669 c/	7244 c/	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM d/	Aero e/ Liq	Osmo f/ Dys	Furun g/	Other
Baseline Coho (Toutle Stock)															
Serial Entry 1	10	1	3	0	1	0	0	0	0	0	0	0	0	0	0
Serial Entry 2	23	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 3	15	0	3	2	1	0	0	0	0	0	0	0	0	1	0
Serial Entry 4	12	1	5	2	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 5	7	0	9	2	0	0	0	0	0	1	0	0	0	0	0
Serial Entry 6	12	0	3	7	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 7	8	0	3	3	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 8	5	0	7	3	2	0	0	0	0	0	0	0	0	0	1
Serial Entry 9	4	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 2.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Spring Chinook											
Carson	200	41	20.5	159	150	9	4.5	144	7.2	6	3.0
Leavenworth	200	74	37.0	126	133	7[a]	3.5	122	61.0	11	5.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD[b]	775[c]	1669[c]	7244[c]	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM[d]	Aero Liq[e]	Osmo Dys[f]	Furun[g]	Other
Spring Chinook															
Carson	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Leavenworth	6	0	3	1	0	0	0	0	0	1	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 2.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Fall Chinook											
Willard Group 1	300	62	20.7	238	205	33	11.0	91	30.3	114	38.0
Willard Group 2	300	49	16.3	251	202	49	16.3	108	36.0	94	31.3
Bonneville (late yearling)	300	168	56.0	132	80	52	17.3	46	15.3	34	11.3
Spring Creek Group 1	303	67	22.1	236	200	36	11.9	83	27.4	117	38.6
Spring Creek Group 2	300	12	4.0	288	276	12	4.0	241	80.3	35	11.7
Willard Group 3	150	43	28.7	107	108	1[a]	0.7	75	50.0	33	22.0
Big White Salmon	150	11	7.3	139	130	9	6.0	116	77.3	14	9.3
Spring Creek Group 3	300	7	2.3	293	275	18	6.0	200	66.7	75	25.0
Bonneville (tules-78 brood)	300	12	4.0	288	181	107	35.7	133	44.3	48	16.0
Elokomin	300	36	12.0	264	210	54	18.0	194	64.7	16	5.3
Little White Salmon	301	37	12.3	263	237	26	8.7	148	49.3	89	29.7
Washougal	300	48	16.0	252	176	76	25.3	122	40.7	54	18.0
Toutle	133	17	12.8	116	99	17	12.8	93	69.9	6	4.5
Kalama Falls	300	41	13.7	259	238	21	7.0	87	29.0	151	50.3
Spring Creek Group 4	300	232	77.3	68	64	4	1.3	54	18.0	10	3.3

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Nega-tive	BKD[b]	775[c]	1669[c]	7244[c]	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM[d]	Aero[e] Liq	Osmo[f] Dys	Furun[g]	Other
Fall Chinook															
Willard Group 1	3	0	0	0	1	0	0	0	0	0	0	0	110	0	0
Willard Group 2	4	1	3	1	0	0	0	0	0	1	0	0	84	0	0
Bonneville (late yearling)	3	2	1	0	0	0	0	0	0	0	0	0	28	0	0
Spring Creek Group 1	6	0	6	3	0	0	0	0	0	0	0	0	102	0	0
Spring Creek Group 2	9	0	21	4	0	1	0	0	0	0	0	0	0	0	0
Willard Group 3	0	0	0	0	0	0	0	0	0	1	0	0	32	0	0
Big White Salmon	1	0	10	2	0	0	0	0	0	0	0	0	0	0	1
Spring Creek Group 3	8	0	14	2	0	0	0	0	0	0	0	0	51	0	0
Bonneville (tules-78 brood)	4	0	7	0	0	0	0	0	0	0	0	0	37	0	0
Elokomin	3	0	6	7	0	0	0	0	0	0	0	0	0	0	0
Little White Salmon	2	0	11	4	0	0	0	0	0	0	0	0	72	0	0
Washougal	0	0	3	1	0	0	0	0	0	0	0	0	50	0	0
Toutle	1	0	4	1	0	0	0	0	0	0	0	0	0	0	0
Kalama Falls	1	0	10	1	0	0	0	0	0	0	0	0	139	0	0
Spring Creek Group 4	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 2.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Steelhead											
Chelan (Leavenworth)	200	16	8.0	184	156	28	14.0	67	33.5	89	44.5
Wells (Winthrop)	200	9	4.5	191	186	5	2.5	32	16.0	154	77.0
Tucannon	200	37	18.5	163	111	52	26.0	51	25.5	60	30.0

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD b/	775 c/	1669 c/	7244 c/	775/ 1669	775/ 7244	1669/ 7244	1699/ BKD	775/ BKD	ERM d/	Aero e/ liq	Osmo f/ dys	Furun g/	Other
Steelhead															
Chelan (Leavenworth)	3	0	20	4	4	0	3	0	0	0	0	0	55	0	0
Wells (Winthrop)	0	0	3	1	1	0	2	0	1	0	0	0	145	0	1
Tucannon	6	0	10	0	0	0	6	0	0	0	1	0	37	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

because of its impact on overall survival and adaptability of the fish. Fall and spring chinook salmon showed immediate effects of osmoregulatory dysfunction in the form of high initial mortality. This is in contrast to coho salmon and steelhead which, in many cases, show the problem over long periods of time.

Seawater adaptability test results and discussion are presented by species in a synopsis format (pages 13 to 180). No comparisons are made between hatcheries or stocks as each group of fish is unique with the exception of those released serially from the same hatchery. Discrepancies between the initial number of fish being tested and the number at the end of a measuring period occurred for most test groups. The unaccounted-for increases or decreases of fish ranged from 0.0 to 47.5% depending on the test group. The discrepancies were attributed to dead fish that were not removed, fish jumping out of pens, and predators. The above discrepancies are evident between the tables and figures showing measurement and visual observation and data. Figures relating environmental data are based upon five-day means; whereas environmental reading stated in the synopsis forms are for specific dates at the time fish entered seawater.

It must be emphasized that the test conditions differ from those found in the natural environment in several important respects: 1) effects of predation cannot be evaluated, 2) no gradual salinity gradient as present in the Columbia River estuary is available to the test groups, and 3) the transfer of the test groups to the Manchester facility imposed conditions not normally encountered by fish released from hatcheries. Among these conditions are physical stresses associated with transportation; confinement; handling; measuring; and, most importantly, direct transfer to seawater. However, all test groups received the same treatment with the exception of exposure to changing environmental conditions that vary with time of seawater entry. Therefore, data for the 1979 experimental period do not represent actual performance of the test groups within their normal environmental and geographic range, but reflect performance under the test conditions in seawater at Manchester.

TEST GROUP SYNOPSIS

Hatchery: Big Creek (Group 1) Species: Coho Stock: Big Creek

Date of Initial Observation: 05-08-79 Termination Date: 11-14-79 Elapsed Days: 190

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 112

Surface Water Temperature at Time of Saltwater entry: 8.8°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.01 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.4 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	7	11	3.5	9.8	13.0	35.7	109.1	155.4
Transitional	129	9	64.5	8.0	22.6	62.6	130.1	182.2
Smolt	64	92	32.0	82.1	26.6	89.8	137.2	204.7
Precocious	0	0	0.0	0.0				
Population	200	112	100.0	100.0	23.5	82.3	131.6	198.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 3 Figure(s): 4

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, 68% of this test group was visually characterized as nonsmolted fish. No mortality directly associated with osmoregulatory stress was observed. By the next observation period (35 days) all fish had the external appearance of smolts. The majority of reversions to a parred state (21%) occurred during the next 37 days. The ratio of smolted to nonsmolted fish after 72 days in seawater remained approximately constant until termination (190 days).

Overall mortality for the first 72 days was less than 10%, with only 1 fish exhibiting clinical symptoms of vibriosis. After that time, the mortality rate increased slowly, until at termination 44% of the original test group had died. The majority of the deaths were attributed to various strains of *V. anguillarum*. No precocious males were observed in this test group.

TABLE 3.--Test group growth and survival at different stages of development during the seawater adaptation study.

Test group		Dates of Observation	Number days between Observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Big Creek Group 1	Coho	05-08-79		length[a/]	109.1 ± 5.080[c/]	130.1 ± 8.646	137.2 ± 9.360		131.7 ± 10.285
				weight[b/]	13.0 ± 2.163	22.6 ± 4.778	26.5 ± 5.800		23.5 ± 5.740
				number	7	129	64	0	200
		06-12-79	35	length			145.6 ± 10.246		145.6 ± 10.246
				weight			33.0 ± 7.370		33.0 ± 7.370
				number	0	0	194	0	194
		07-19-79	37	length	135.3 ± 6.552	141.4 ± 7.742	157.2 ± 11.109		153.4 ± 12.775
				weight	22.8 ± 5.105	30.8 ± 6.775	42.9 ± 10.358		39.8 ± 11.456
				number	12	27	142	0	181
		08-27-79	39	length	135.1 ± 7.120	146.1 ± 11.244	169.0 ± 12.825		164.1 ± 16.154
				weight	22.3 ± 5.998	32.4 ± 8.663	53.8 ± 13.574		49.2 ± 15.965
				number	8	21	123	0	152
		11-14-79	79	length	155.4 ± 10.529	182.2 ± 5.585	204.7 ± 16.400		198.0 ± 21.677
				weight	35.7 ± 8.687	62.6 ± 9.528	89.8 ± 24.196		82.3 ± 28.046
				number	11	9	92	0	112

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

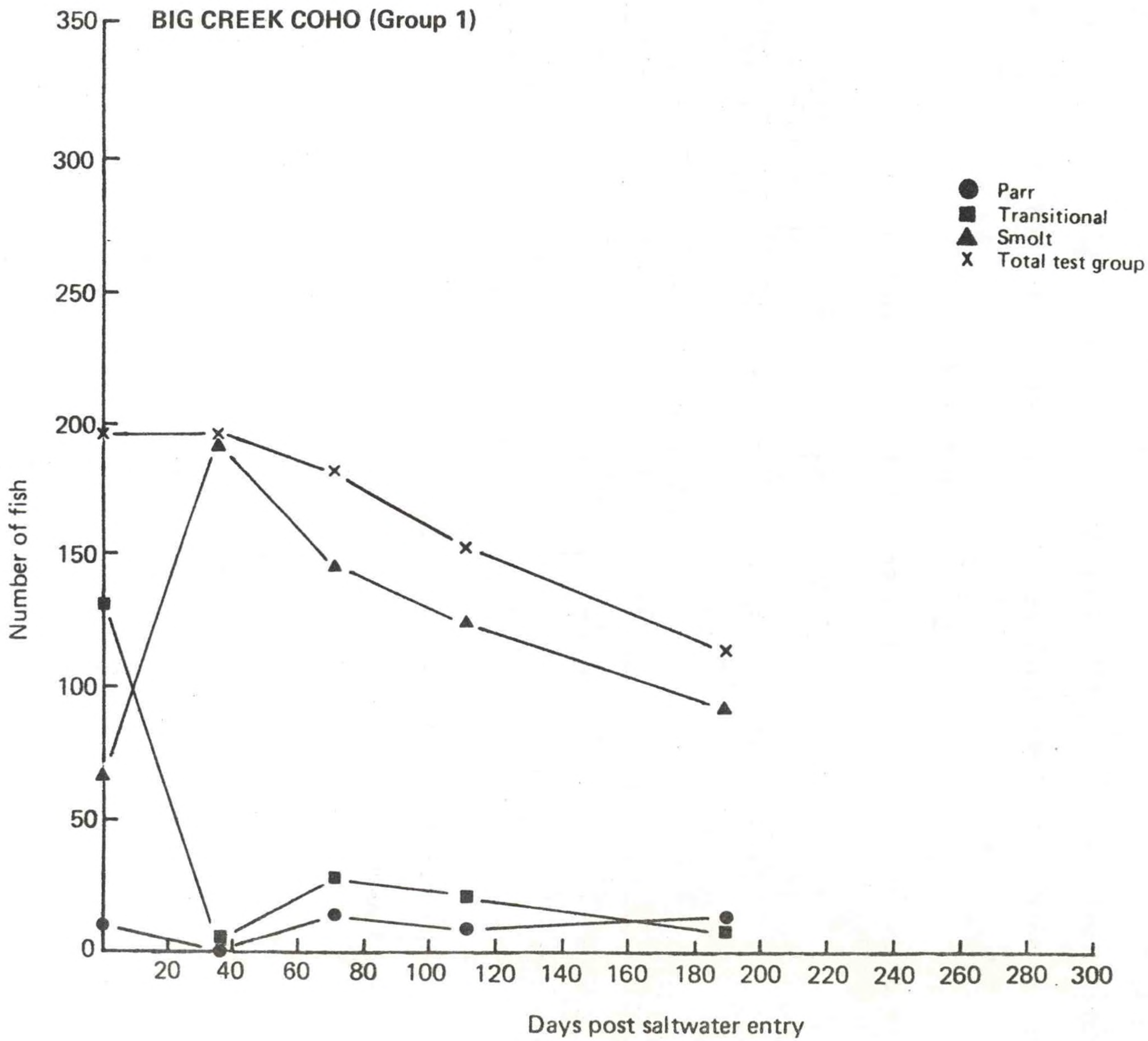


Figure 4.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Cascade (Group 1) Species: Coho Stock: Sandy

Date of Initial Observation: 05-08-79 Termination Date: 11-15-79 Elapsed Days: 191

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 82

Surface Water Temperature at Time of Saltwater entry: 8.8°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.01 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.4 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	8	15	4.0	18.3	9.7	37.9	97.1	156.5
Transitional	172	11	86.0	13.4	19.1	60.7	124.7	182.7
Smolt	20	56	10.0	68.3	25.8	89.6	138.8	205.0
Precocious	0	0	0.0	0.0				
Population	200	82	100.0	100.0	19.4	76.3	125.0	193.1

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 4 Figure(s): 5

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, 90% of this test group were visually characterized as nonsmolted fish; however, after 35 days, 97% had assumed the external appearance of smolts. Thereafter, reversions to a parred state occurred, and by the termination of the study (191 days), 32% of the fish remaining were visually judged to be nonsmolted fish. No direct losses attributed to osmoregulatory stress were observed.

Vibrio anguillarum was first isolated from dead fish in mid-July and continued to be the major identifiable bacterial pathogen in this test group. Strain 775 was not commonly isolated. Overall mortality in this test group was 59%.

No precocious males were observed.

TABLE 4 .--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Cascade Group 1	Coho	05-08-79		length a/	97.1 ± 16.889 c/	124.7 ± 7.995	138.9 ± 3.801		125.0 ± 10.813
				weight b/	9.7 ± 4.380	19.1 ± 3.788	25.8 ± 2.415		19.4 ± 4.646
				number	8	172	20	0	200
		06-12-79	35	length	90.0 ± 0.000	130.3 ± 4.349	140.2 ± 9.120		139.7 ± 9.801
				weight	8.4 ± 0.000	23.5 ± 2.714	28.5 ± 5.517		28.3 ± 5.685
				number	1	4	191	0	196
		07-19-79	37	length	135.8 ± 4.738	140.6 ± 7.624	150.6 ± 9.356		147.8 ± 10.085
				weight	23.8 ± 3.287	29.1 ± 5.414	36.9 ± 7.276		34.6 ± 7.874
				number	9	35	126	0	170
		08-28-79	40	length	141.5 ± 7.502	146.6 ± 9.199	163.4 ± 11.051		159.2 ± 13.132
				weight	28.3 ± 7.018	30.5 ± 6.910	46.8 ± 10.403		43.0 ± 12.053
				number	10	18	97	0	125
		11-15-79	79	length	156.5 ± 12.484	182.7 ± 9.696	205.0 ± 14.222		193.1 ± 23.153
				weight	37.9 ± 10.767	60.7 ± 12.617	89.6 ± 22.277		76.3 ± 28.356
				number	15	11	56	0	82

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

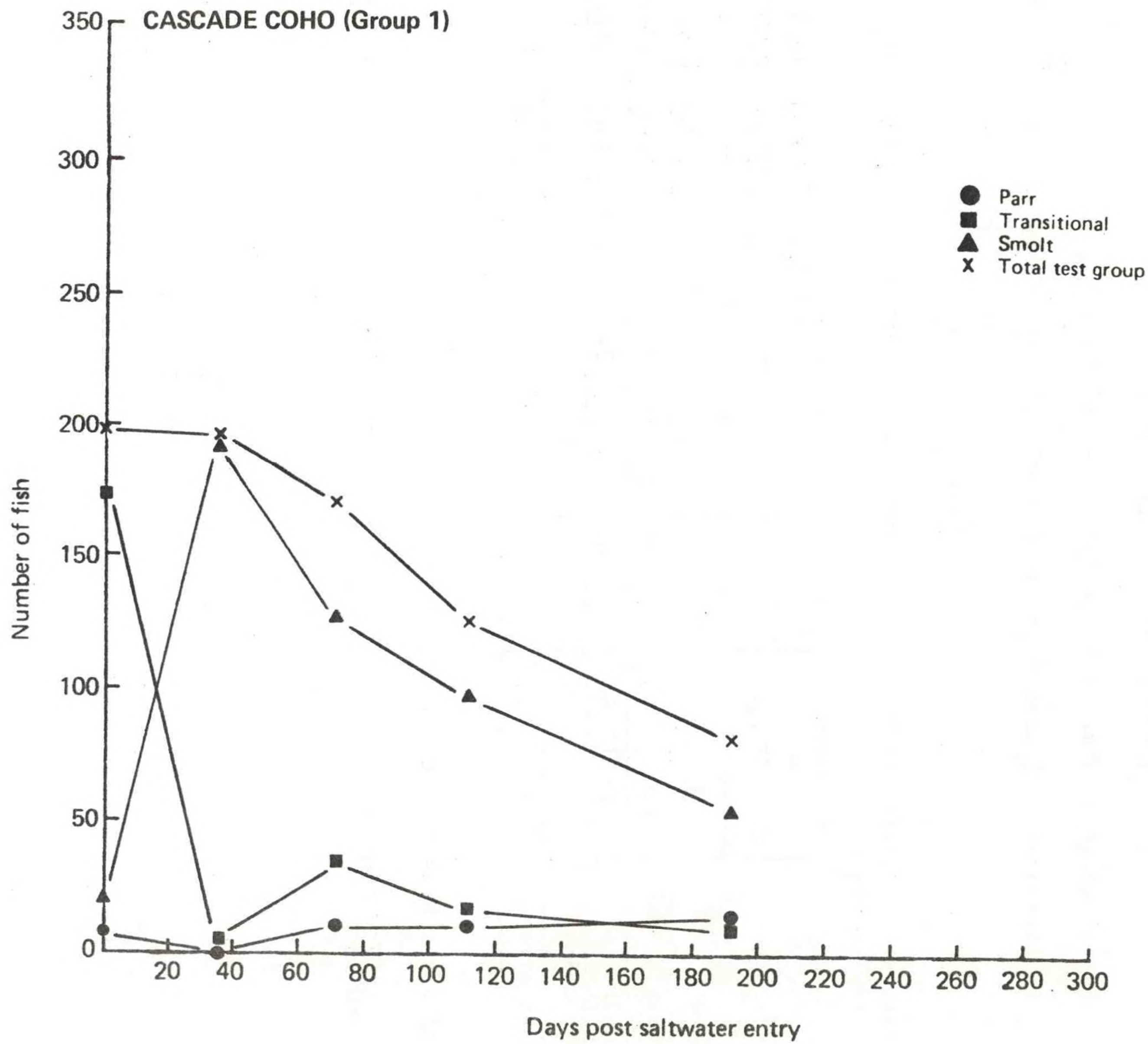


Figure 5.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle (Group 1)   Species: Coho   Stock: Green River

Date of Initial Observation: 05-08-79   Termination Date: 11-14-79   Elapsed Days: 190

Number of Replicates: 1   Total No. of Fish at Start: 200
Total No. of Fish at Termination: 92

Surface Water Temperature at Time of Saltwater entry: 8.8°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.5 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.01 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.4   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	16	15	8.0	16.3	17.1	42.3	118.1	163.7
Transitional	166	13	83.0	14.1	23.8	65.9	131.7	186.1
Smolt	18	64	9.0	69.6	31.6	100.2	144.9	212.1
Precocious	0	0	0.0	0.0				
Population	200	92	100.0	100.0	24.0	85.9	131.8	200.5

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 5   Figure(s): 6

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, only 9% of the test group were visually characterized as smolted fish, with the remainder appearing primarily as transitional stage fish. After 35 days, however, 99% of the fish remaining had assumed the external appearance of smolts. By termination of the study, 30% of the remaining fish had reverted to a nonsmolt status. No mortalities directly associated with osmoregulatory stress were observed.

Vibrio anguillarum was the only bacterial pathogen isolated from the test group. This pathogen was initially isolated from the group in late July and continued to November. Strain 775 was the most prevalent.

Total mortality for the entire experiment (190 days) was 54%, with most of this attributed to vibriosis.

No precocious males were observed in this test group.

TABLE 5 .--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Toutle Group 1	Coho	05-08-79		length[a/]	118.1 ± 5.352[c/]	131.8 ± 6.844	144.9 ± 4.788		131.8 ± 8.572
				weight[b/]	17.2 ± 2.894	23.9 ± 3.783	31.6 ± 3.674		24.0 ± 4.757
				number	16	166	18	0	200
		06-12-79	35	length	118.0 ± 0.000	141.0 ± 0.000	147.9 ± 8.661		147.7 ± 8.890
				weight	13.5 ± 0.000	25.4 ± 0.000	35.2 ± 6.817		35.0 ± 6.991
				number	1	1	194	0	196
		07-20-79	38	length	135.7 ± 9.673	147.0 ± 7.765	159.7 ± 8.847		156.7 ± 10.734
				weight	23.8 ± 6.541	33.0 ± 6.121	42.5 ± 7.445		40.2 ± 8.651
				number	7	31	146	0	184
		08-28-79	39	length	143.7 ± 8.883	152.0 ± 5.625	172.0 ± 11.800		169.0 ± 13.719
				weight	29.2 ± 5.769	33.5 ± 4.778	53.6 ± 11.466		50.8 ± 13.054
				number	7	12	130	0	149
		11-14-79	78	length	163.7 ± 11.055	186.1 ± 12.835	212.1 ± 11.913		200.5 ± 22.036
				weight	42.3 ± 12.434	65.9 ± 13.809	100.2 ± 20.876		85.9 ± 29.404
				number	15	13	64	0	92

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

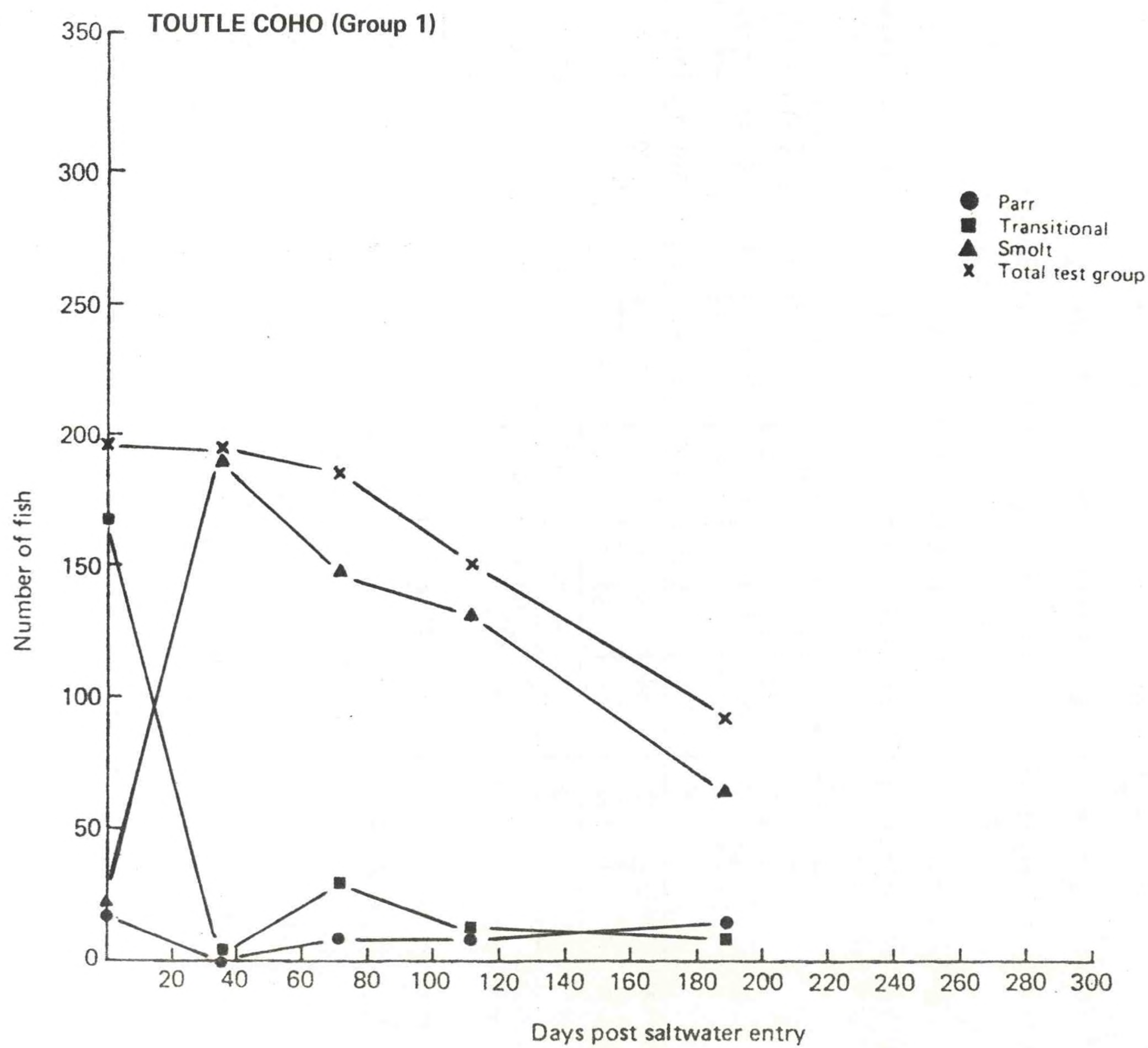


Figure 6.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Washougal (Group 1)   Species: Coho   Stock: Cowlitz

Date of Initial Observation: 05-08-79   Termination Date: 11-15-79   Elapsed Days: 191

Number of Replicates: 1   Total No. of Fish at Start: 200
Total No. of Fish at Termination: 66

Surface Water Temperature at Time of Saltwater entry: 10.9°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.62 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 7.3   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	11	7	5.5	10.6	13.3	45.2	108.1	167.1
Transitional	82	10	41.0	15.2	23.0	52.9	130.2	176.8
Smolt	107	49	53.5	74.2	28.8	94.1	140.5	207.9
Precocious	0	0	0.0	0.0				
Population	200	66	100.0	100.0	25.5	82.7	134.5	198.9

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 6   Figure(s): 7

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, approximately 53% of this test group was visually characterized as smolted. After 35 days, 98% of the fish remaining had assumed the external appearance of smolts. By termination (191 days), 74% of those fish remaining were smolted.

There were few mortalities observed until *Vibrio anguillarum* was first isolated in late June. After this time, both Strain 775 and Strain 1669 were consistently isolated from dead fish up to termination in November.

Overall mortality was 67%, due primarily to vibriosis.

No precocious males were observed in this test group.

TABLE 6 .--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Washougal Group 1	Coho	05-08-79		length[a]	108.1 ± 8.595[c]	130.2 ± 7.367	140.5 ± 6.616		134.5 ± 10.721
				weight[b]	13.3 ± 3.661	23.0 ± 4.164	28.8 ± 4.326		25.6 ± 5.845
				number	11	82	107	0	200
		06-12-79	35	lenght		120.8 ± 14.974	144.4 ± 9.129		144.0 ± 9.823
				weight		19.0 ± 5.683	31.8 ± 6.399		31.5 ± 6.630
				number	0	4	189	0	193
		07-20-79	38	length	118.0 ± 14.537	137.0 ± 6.185	153.4 ± 10.435		150.6 ± 12.554
				weight	15.7 ± 6.504	25.3 ± 3.605	37.5 ± 8.397		35.5 ± 9.405
				number	4	17	131	0	152
		08-28-79	39	length	134.0 ± 0.000	144.8 ± 6.296	164.8 ± 11.545		162.8 ± 12.759
				weight	26.3 ± 0.000	29.3 ± 6.374	47.9 ± 11.576		46.2 ± 12.451
				number	1	8	89	0	98
		11-15-79	79	length	167.1 ± 14.100	176.8 ± 10.507	207.9 ± 16.937		198.9 ± 22.135
				weight	45.2 ± 12.828	52.9 ± 10.019	94.1 ± 27.386		82.7 ± 31.141
				number	7	10	49	0	66

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

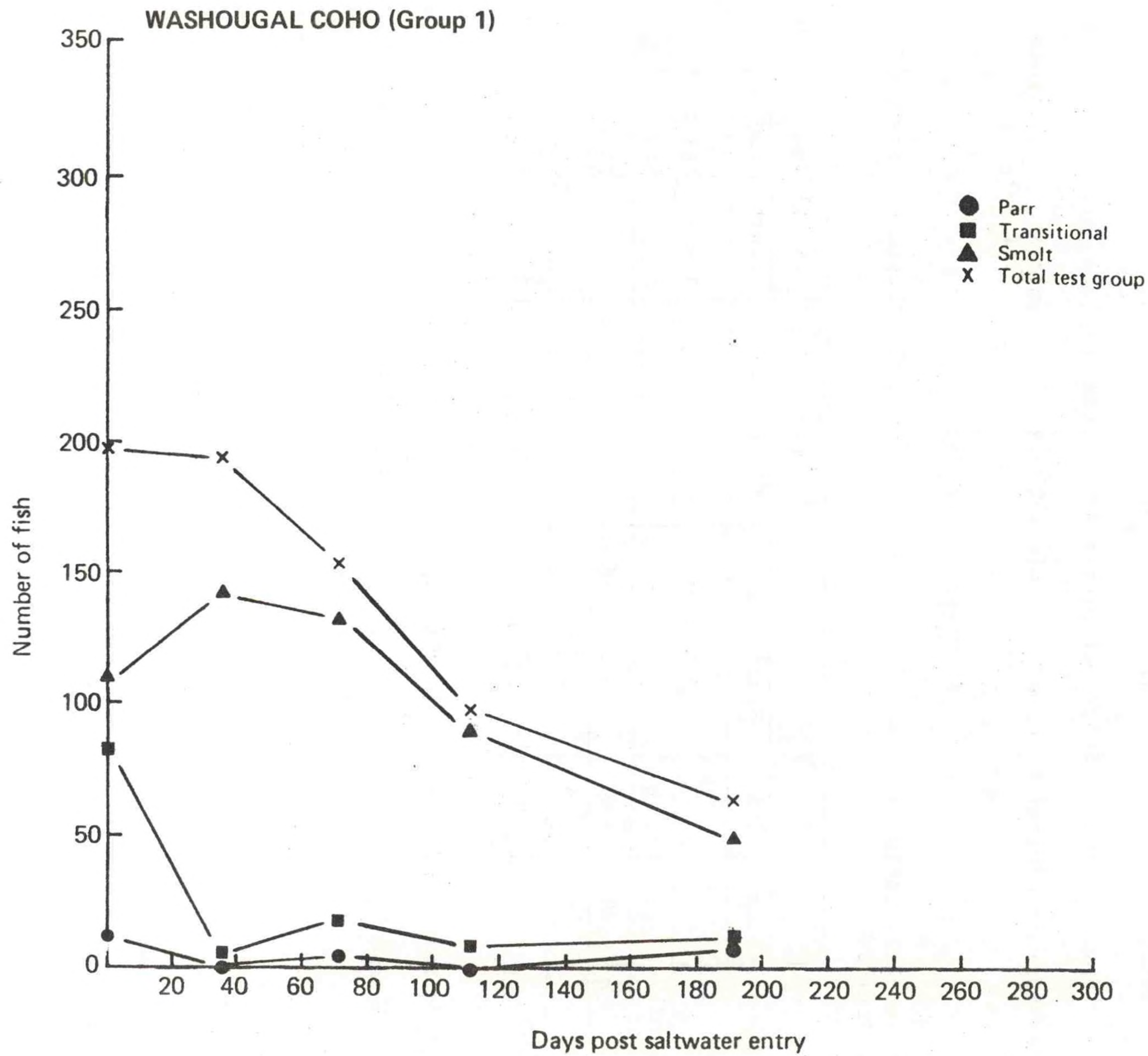


Figure 7.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Big Creek (Group 2) Species: Coho Stock: Big Creek

Date of Initial Observation: 06-08-79 Termination Date: 11-14-79 Elapsed Days: 158

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 64

Surface Water Temperature at Time of Saltwater entry: No Reading Figure: 3

Surface Salinity at Time of Saltwater Entry: No Reading Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No Reading Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	7	7	3.5	10.5	14.9	43.7	116.7	165.9
Transitional	144	8	72.0	12.5	22.1	63.4	131.7	184.1
Smolt	49	49	24.5	76.6	28.4	98.9	143.2	209.5
Precocious	0	0	0.0	0.0				
Population	200	64	100.0	100.0	23.4	88.4	134.0	201.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 7 Figure(s): 8

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of seawater entry, almost 75% of the fish in this test group were visually characterized as transitional stage fish. After 42 days, more than 98% of these fish appeared to have successfully smolted. No fish died directly from osmoregulatory stress. By the termination of the study (159 days), approximately 23% of those fish remaining had reverted to a parred or transitional state.

Vibrio (Strains 775 and 1669) was the major bacterial agent isolated from moribund fish. This pathogen became a problem 42 days after seawater entry. Vibrio was associated with 68% of the mortalities experienced by this test group.

Overall mortality was 68%.

No precocious males were observed in the Big Creek Coho Group 2 test group.

TABLE 7 .-- Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Big Creek Group 2	Coho	06-08-79		length[a/]	116.7 ± 3.545[c/]	131.7 ± 8.092	143.2 ± 6.536		134.0 ± 9.627
				weight[b/]	14.9 ± 1.298	22.1 ± 4.260	28.4 ± 4.313		23.4 ± 5.241
				number	7	144	49	0	200
		07-20-79	42	length		127.0 ± 5.000	145.8 ± 10.137		145.5 ± 10.334
				weight		18.3 ± 4.158	29.7 ± 6.301		29.5 ± 6.422
				number	0	3	192	0	195
		08-28-78	39	length	138.0 ± 0.000	146.7 ± 4.855	163.1 ± 12.340		161.5 ± 12.906
				weight	20.8 ± 0.000	28.9 ± 4.207	46.2 ± 12.125		44.5 ± 12.805
				number	1	7	77	0	85
		11-14-79	78	length	165.9 ±11.393	184.1 ± 12.426	209.5 ± 15.293		201.6 ± 20.913
				weight	43.7 ± 8.639	63.4 ± 12.643	98.9 ± 24.944		88.4 ± 29.766
				number	7	8	49	0	64

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

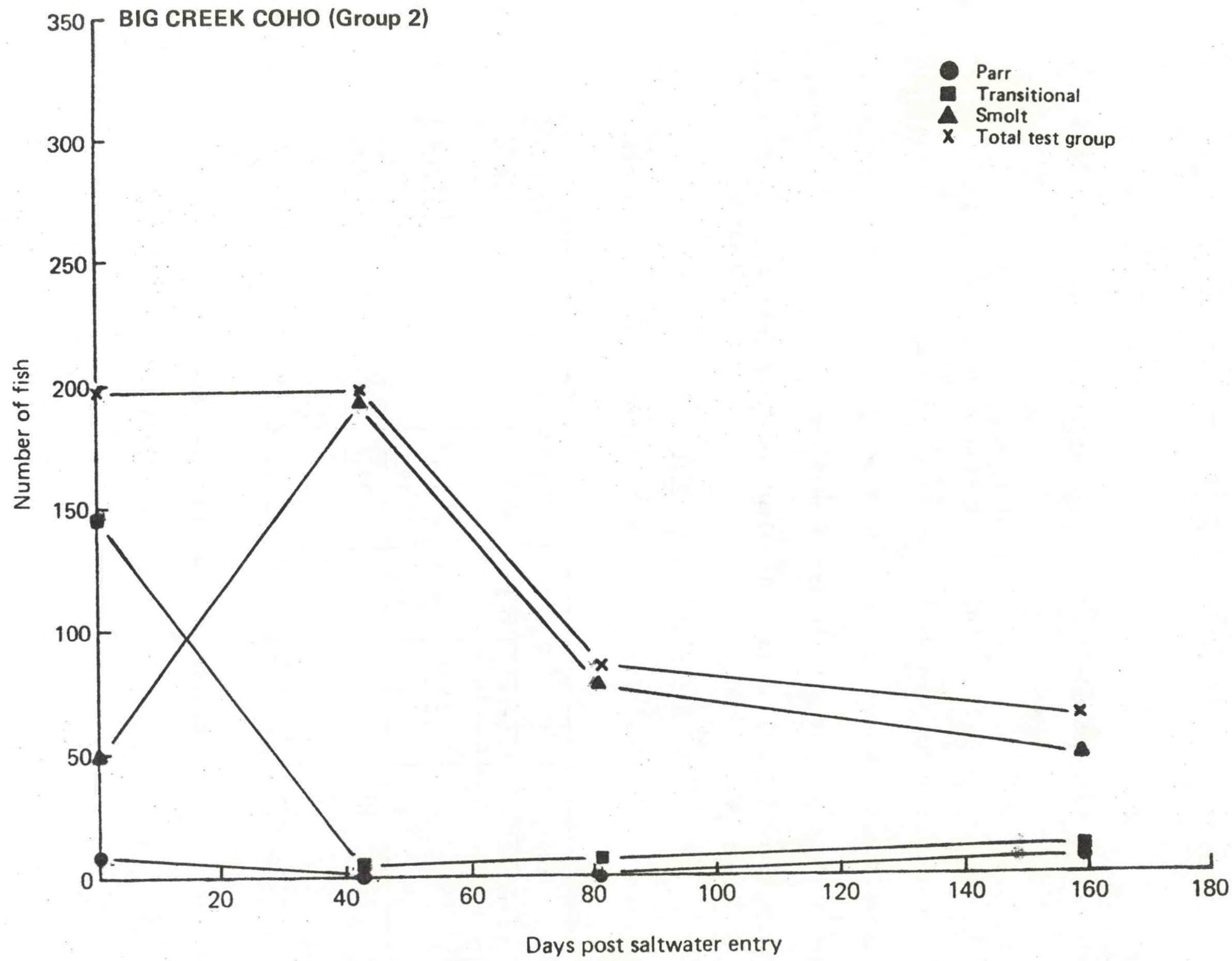


Figure 8.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Cascade (Group 2)
Species: Coho
Stock: Sandy

Date of Initial Observation: 06-08-79
Termination Date: 11-19-79
Elapsed Days: 164

Number of Replicates: 1
Total No. of Fish at Start: 200
Total No. of Fish at Termination: 104

Surface Water Temperature at Time of Saltwater entry: No Reading — Figure: 3

Surface Salinity at Time of Saltwater Entry: No Reading — Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No Reading — Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading — Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	29	23	14.5	22.1	13.8	35.8	113.4	155.0
Transitional	149	20	74.5	19.2	19.7	50.7	127.2	175.4
Smolt	22	61	11.0	58.7	25.6	77.8	139.3	199.0
Precocious	0	0	0.0	0.0				
Population	200	104	100.0	100.0	19.5	63.3	126.6	184.7

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 8
Figure(s): 9

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, approximately 75% of this test group were visually judged to be transitional stage fish, 14% parr, and 11% smolts. After 45 days in seawater, 33% of the fish showed no external signs of smolting, and after 81 days, 27% of this test group still had not smolted. By the termination of study (164 days), 41% of the remaining fish were visually characterized as nonsmolts.

Vibrio (Strains 775 and 1669) was the major bacterial pathogen isolated from moribund fish in this test group. BKD was isolated from one fish. There were no mortalities associated with osmoregulatory dysfunction. Overall mortality was 48%. No precocious males were observed.

TABLE 8 .-- Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Cascade Group 2	Coho	06-08-79		length[a/]	113.5 ± 6.889[c/]	127.3 ± 6.448	139.3 ± 6.714		126.6 ± 9.261
				weight[b/]	13.8 ± 2.451	19.7 ± 3.216	25.6 ± 4.176		19.5 ± 4.404
				number	29	149	22	0	200
		07-23-79	45	length	120.3 ± 8.311	131.5 ± 6.185	146.5 ± 8.188		141.2 ± 10.922
				weight	17.1 ± 2.795	21.5 ± 3.442	29.6 ± 5.241		26.8 ± 6.221
				number	6	56	126	0	188
		08-28-79	36	length	130.6 ± 9.361	142.2 ± 6.102	160.3 ± 10.288		153.8 ± 14.734
				weight	21.9 ± 5.093	28.6 ± 4.646	42.4 ± 8.533		37.8 ± 11.018
				number	23	22	122	0	167
		11-19-79	83	length	155.0 ± 11.872	175.4 ± 7.407	199.0 ± 12.898		184.7 ± 21.697
				weight	35.8 ± 8.417	50.7 ± 7.917	77.8 15.581		63.3 ± 22.164
				number	23	20	61	0	104

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

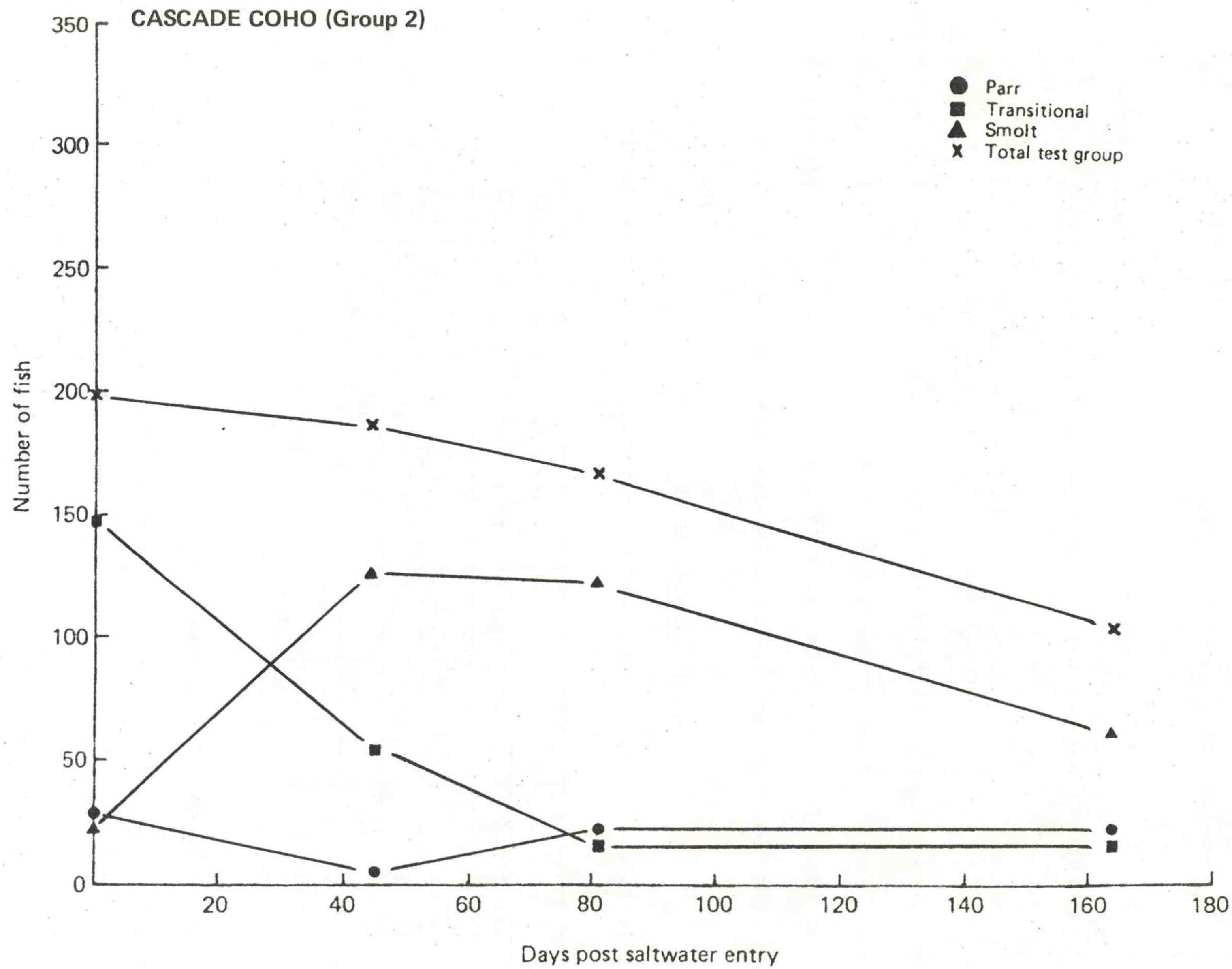


Figure 9.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle (Group 2) Species: Coho Stock: Green River

Date of Initial Observation: 06-14-79 Termination Date: 11-19-79 Elapsed Days: 158

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 72

Surface Water Temperature at Time of Saltwater entry: 11.6°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.69 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	29	3	29.0	4.2	16.6	42.3	119.5	163.0
Transitional	124	9	124.0	12.5	21.7	51.3	130.3	171.7
Smolt	47	60	47.0	83.3	25.7	89.1	137.9	203.3
Precocious	0	0	0.0	0.0				
Population	200	72	200.0	100.0	21.9	82.4	130.5	197.7

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 9 Figure(s): 10

OVERALL SEAWATER ADAPTATION

COMMENTS

At introduction to seawater, slightly over 75% of this test group were visually characterized as either parred or transitional stage fish. After 39 days in seawater, over 90% of the fish exhibited the external characteristics of smolted fish. At the termination of the study, more than 83% of those fish remaining were judged to be smolts. No direct losses attributed to osmoregulatory dysfunction were observed in this group.

Losses due to disease were not severe until after 40 days, when vibriosis was first isolated from dead fish (Strains 1669, 775, and a combination of the two strains). Losses due to vibriosis were severe between 29 August 79 and 19 November 1979 when mortality exceeded 50%.

This test group had little difficulty adapting to seawater. A low resistance to Vibrio infection seems to be a major factor affecting the overall survival of this test group. After 158 days in seawater, cumulative mortality was 64%.

There were no precocious males observed in this test group.

TABLE 9 .-- Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Group 2	Coho	06-14-79		length[a/]	119.5 ± 4.656[c/]	130.3 ± 5.471	137.9 ± 5.300		130.5 ± 7.660
				weight[b/]	16.6 ± 2.270	21.7 ± 2.806	25.7 ± 3.190		21.9 ± 3.949
				number	29	124	47	0	200
		07-23-79	39	length	123.0 ± 0.000	127.5 ± 8.319	146.3 ± 7.694		144.6 ± 9.420
				weight	19.1 ± 0.000	18.6 ± 4.253	29.6 ± 4.940		28.6 ± 5.773
				number	1	16	176	0	193
		08-29-79	37	length	131.7 ± 7.945	143.6 ± 7.429	161.1 ± 10.267		157.7 ± 12.938
				weight	21.4 ± 6.176	28.7 ± 6.015	44.5 ± 9.455		41.7 ± 11.333
				number	10	14	136	0	160
		11-19-79	82	length	163.0 ± 9.539	171.7 ± 7.314	203.3 ± 16.162		197.7 ± 19.730
				weight	42.3 ± 11.789	51.3 ± 9.904	89.1 ± 22.634		82.4 ± 25.858
				number	3	9	60	0	72

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

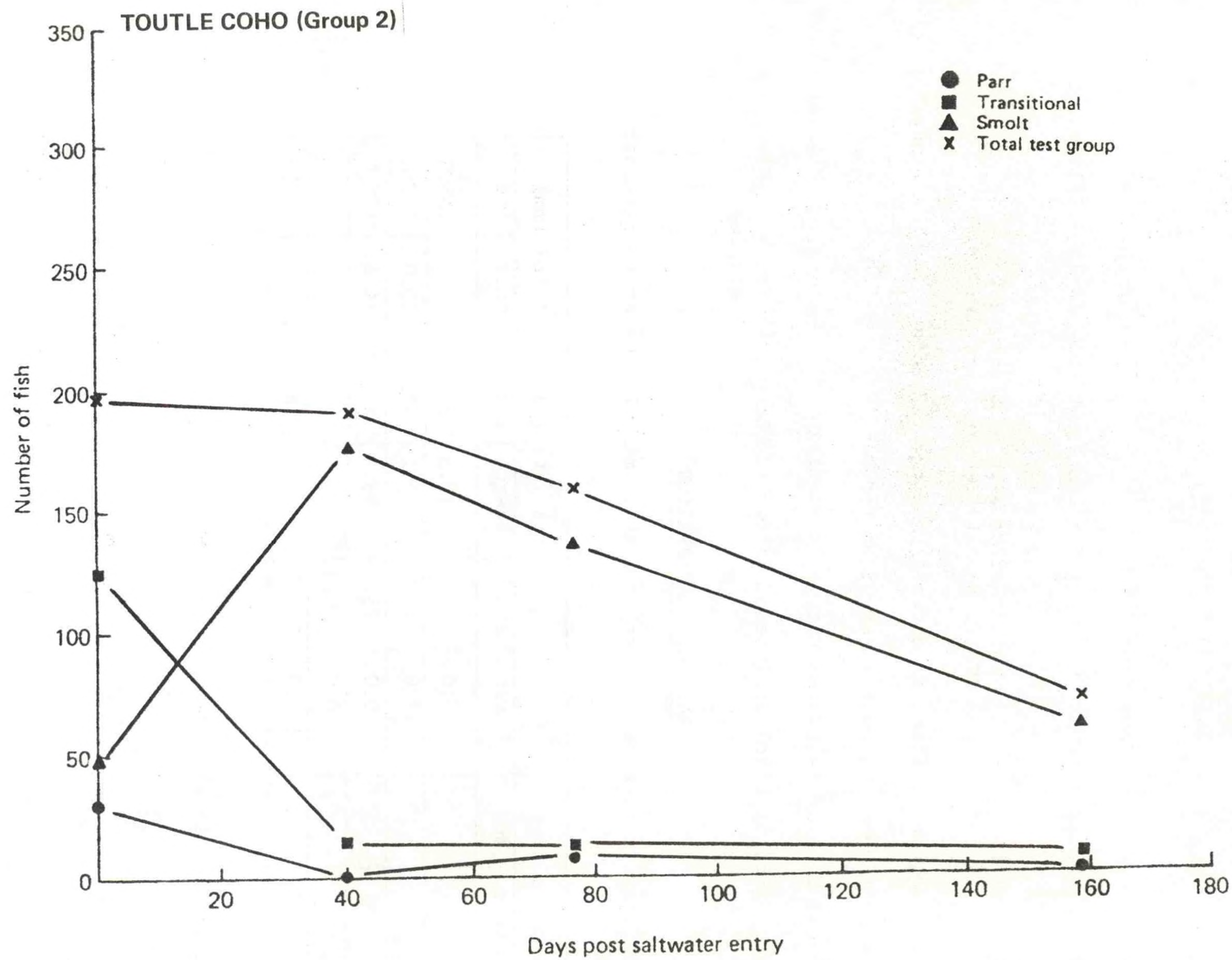


Figure 10.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Washougal (Group 2) Species: Coho Stock: Cowlitz

Date of Initial Observation: 06-08-79 Termination Date: 11-19-79 Elapsed Days: 164

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 77

Surface Water Temperature at Time of Saltwater entry: No Reading Figure: 3

Surface Salinity at Time of Saltwater Entry: No Reading Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No Reading Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	6	8	3.0	10.4	13.5	36.7	111.3	155.5
Transitional	36	11	18.0	14.3	18.1	51.0	123.0	175.2
Smolt	158	58	79.0	75.3	23.6	87.0	134.4	202.9
Precocious	0	0	0.0	0.0				
Population	200	77	100.0	100.0	22.3	76.6	131.7	194.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 10 Figure(s): 11

OVERALL SEAWATER ADAPTATION

COMMENTS:

At seawater entry, 79% of these fish were visually characterized as smolts, 18% as transitionals, and 3% as parrs. After 82 days in seawater, 87% of those fish remaining were judged to have smolted, and at termination of the study (164 days), 75% of the fish were smolts.

Vibrio Strain 775 was the bacterial pathogen most often isolated from dead fish in this test group. This pathogen was observed throughout the entire seawater holding period. *Vibrio* Strain 1669 was not observed. BKD was isolated on one occasion. No losses due to immediate osmoregulatory dysfunction were observed. At termination, total mortality was approximately 62%.

No precocious males were observed in this test group.

TABLE 10.-- Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Washougal Group 2	Coho	06-08-79		length[a]	111.3 ± 5.316[c]	123.0 ± 6.695	134.4 ± 7.457		131.7 ± 9.185
				weight[b]	13.5 ± 2.131	18.1 ± 3.329	23.6 ± 4.673		22.3 ± 5.126
				number	6	36	158	0	200
		07-24-79	46	length		130.0 ± 7.743	146.3 ± 10.077		143.8 ± 11.353
				weight		20.6 ± 3.786	30.3 ± 7.351		28.8 ± 7.751
				number	0	26	146	0	172
		08-29-79	36	length	130.7 ± 7.572	136.0 ± 6.622	157.1 ± 12.923		154.3 ± 14.337
				weight	22.8 ± 4.588	25.5 ± 4.664	42.3 ± 12.324		40.1 ± 12.981
				number	3	15	122	0	140
		11-19-79	82	length	155.5 ± 10.664	175.2 ± 8.159	202.9 ± 19.119		194.0 ± 23.692
				weight	36.7 ± 6.885	51.0 ± 6.096	87.0 ± 28.808		76.6 ± 31.251
				number	8	11	58	0	77

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

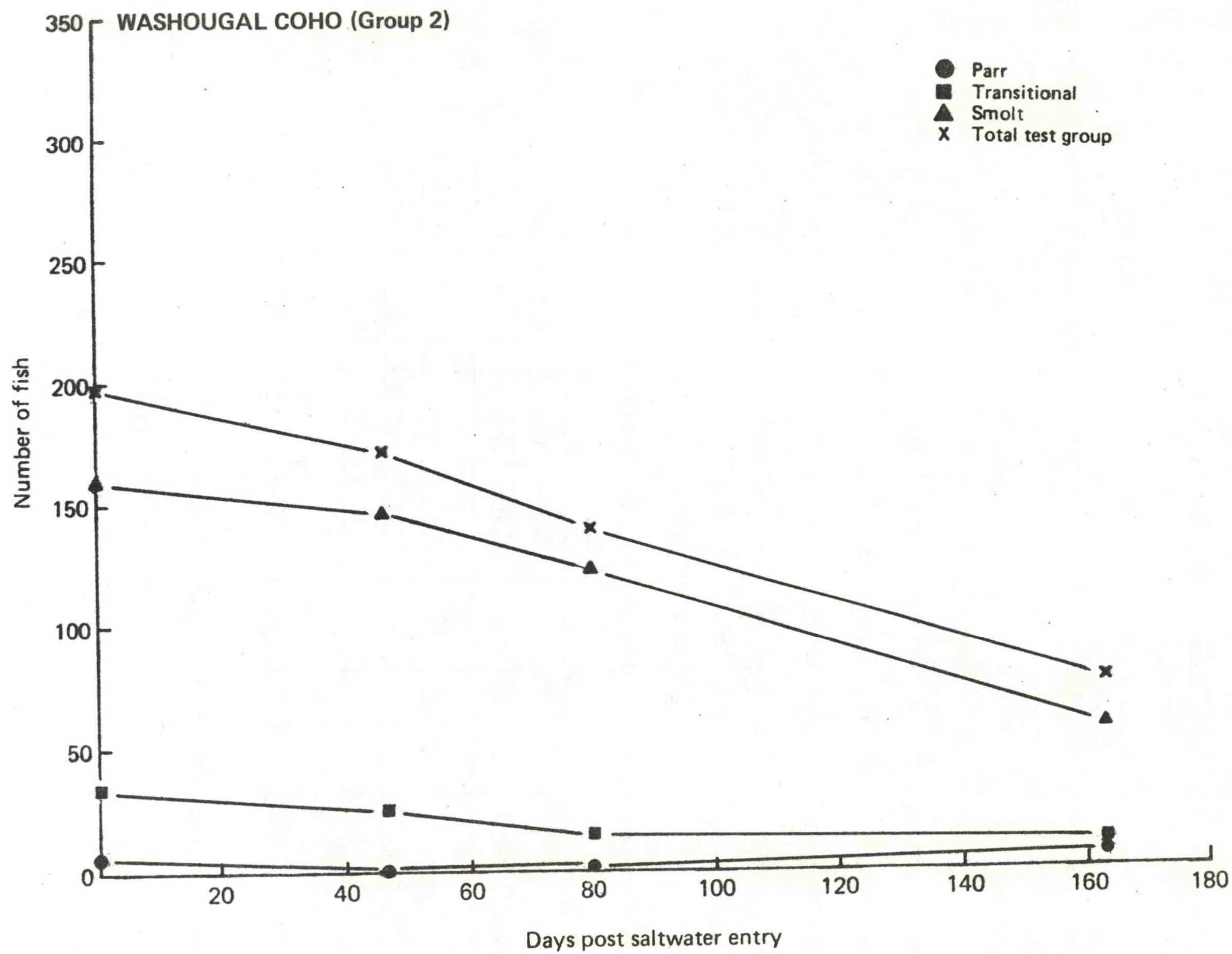


Figure 11.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Big Creek (Group 3) Species: Coho Stock: Big Creek

Date of Initial Observation: 07-09-79 Termination Date: 11-14-79 Elapsed Days: 128

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 77

Surface Water Temperature at Time of Saltwater entry: 11.2°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.04 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.2 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	30	15	15.0	19.5	17.1	38.9	118.9	158.1
Transitional	165	20	82.5	26.0	24.8	50.2	136.4	170.8
Smolt	5	42	2.5	54.5	31.1	77.0	146.8	194.0
Precocious	0	0	0.0	0.0				
Population	200	77	100.0	100.0	23.8	62.6	134.1	181.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 11 Figure(s): 12

OVERALL SEAWATER ADAPTATION

COMMENTS

At entry to seawater, the majority (82%) of the fish in this test group were visually characterized as in a transitional stage, with less than 3% appearing to be smolts. After 51 days in seawater, 82% of those fish remaining had the external appearance of smolts; however, at the end of the study (128 days), the percentage of smolted fish in the test group had declined to 55%.

Mortality attributable to *Vibrio anguillarum* (Strain 1669) was first observed after approximately 25 days in seawater. *Vibrio*-related deaths (primarily Strain 775) continued for the duration of the experiment. By termination, total mortality of this group was 61%, with the mortality rate increasing dramatically during the last 45 days. The mean weight for dead fish was 25 g compared to 62 g for the survivors. The lower mean weight and high rate of reversion to a nonsmolted state suggest that long-term osmoregulatory stress was a major factor limiting the performance of this group.

No precocious males were observed.

TABLE 11.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Big Creek Group 3	Coho	07-09-79		length[a/]	118.9 ± 10.961[c/]	136.4 ± 8.675	146.8 ± 10.569		134.1 ± 11.182
				weight[b/]	17.1 ± 3.909	24.8 ± 4.980	31.1 ± 6.011		23.8 ± 5.694
				number	30	165	5	0	200
		08-29-79	51	length	130.0 ± 13.010	137.7 ± 7.664	153.9 ± 10.269		150.5 ± 12.379
				weight	18.9 ± 4.358	23.2 ± 4.123	35.8 ± 8.059		33.3 ± 9.218
				number	9	24	148	0	181
		11-14-79	77	length	158.1 ± 12.589	170.8 ± 10.978	194.0 ± 12.788		181.0 ± 19.306
				weight	38.9 ± 11.738	50.2 ± 10.126	77.0 ± 19.253		62.6 ± 22.739
				number	15	20	42	0	77

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

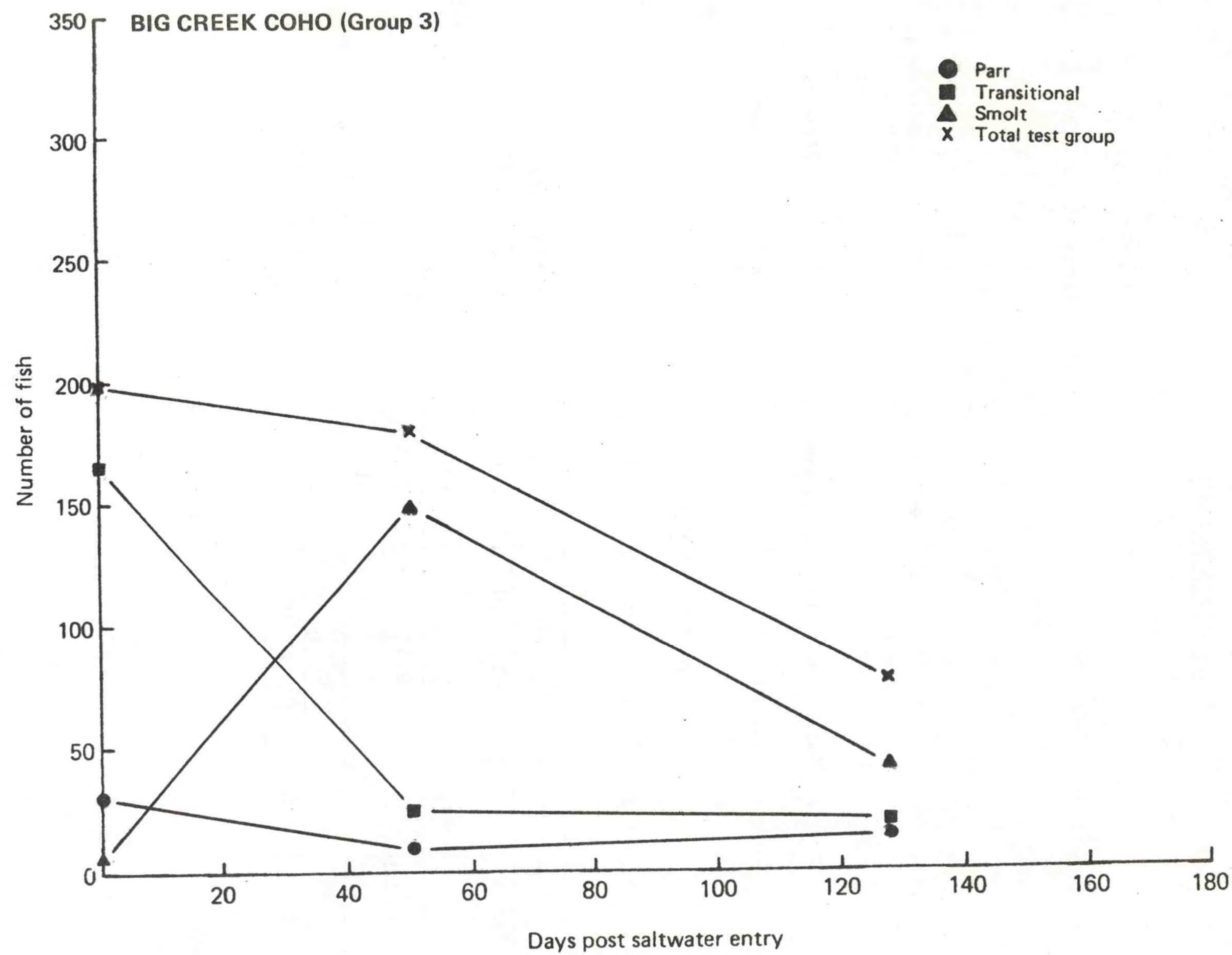


Figure 12.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Cascade (Group 3)   Species: Coho   Stock: Sandy

Date of Initial Observation: 07-09-79   Termination Date: 11-19-79   Elapsed Days: 133

Number of Replicates: 1   Total No. of Fish at Start: 200
Total No. of Fish at Termination: 70

Surface Water Temperature at Time of Saltwater entry: 11.2°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.04 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.2   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	76	24	38.0	34.3	16.1	32.6	117.6	151.2
Transitional	121	21	60.5	30.0	21.6	49.1	131.0	171.6
Smolt	3	25	1.5	35.7	31.2	74.3	145.0	195.2
Precocious	0	0	0.0	0.0				
Population	200	70	100.0	100.0	19.6	52.4	126.1	173.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 12   Figure(s): 13

OVERALL SEAWATER ADAPTATION

COMMENTS

Only a few fish in this test group appeared to be smolted when introduced into seawater. After 51 days, only half (90) of the surviving fish had the external appearance of smolts. At the termination of the study (133 days), the test group contained about equal numbers of smolt, transition, and parr stage fish.

Mortality due to *Vibrio anguillarum* was first noticed after 30 days in seawater and continued for the duration of the experiment, with Strain 775 being the most prevalent. The mortality rate showed a sharp increase at about 90 days. Most of the dead fish were markedly smaller than the mean test group size--an indication of possible long-term osmoregulatory stress. Overall mortality for the test group was 65%.

No precocious males were observed.

TABLE 12.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Cascade Group 3	Coho	07-09-79		length[a]	117.6 ± 7.073[c]	131.0 ± 7.795	145.0 ± 10.817		126.1 ± 10.213
				weight[b]	16.1 ± 2.851	21.6 ± 4.019	31.2 ± 7.545		19.6 ± 4.740
				number	76	121	3	0	200
		08-29-79	51	length	124.6 ± 7.145	138.8 ± 6.769	152.4 ± 9.792		143.2 ± 13.474
				weight	17.2 ± 3.909	24.4 ± 4.086	34.2 ± 7.164		28.1 ± 8.840
				number	31	57	90	0	178
		11-19-79	82	length	151.2 ± 11.096	171.6 ± 9.765	195.2 ± 14.226		173.0 ± 21.972
				weight	32.6 ± 8.080	49.1 ± 10.098	74.3 ± 16.860		52.4 ± 21.531
				number	24	21	25	0	70

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

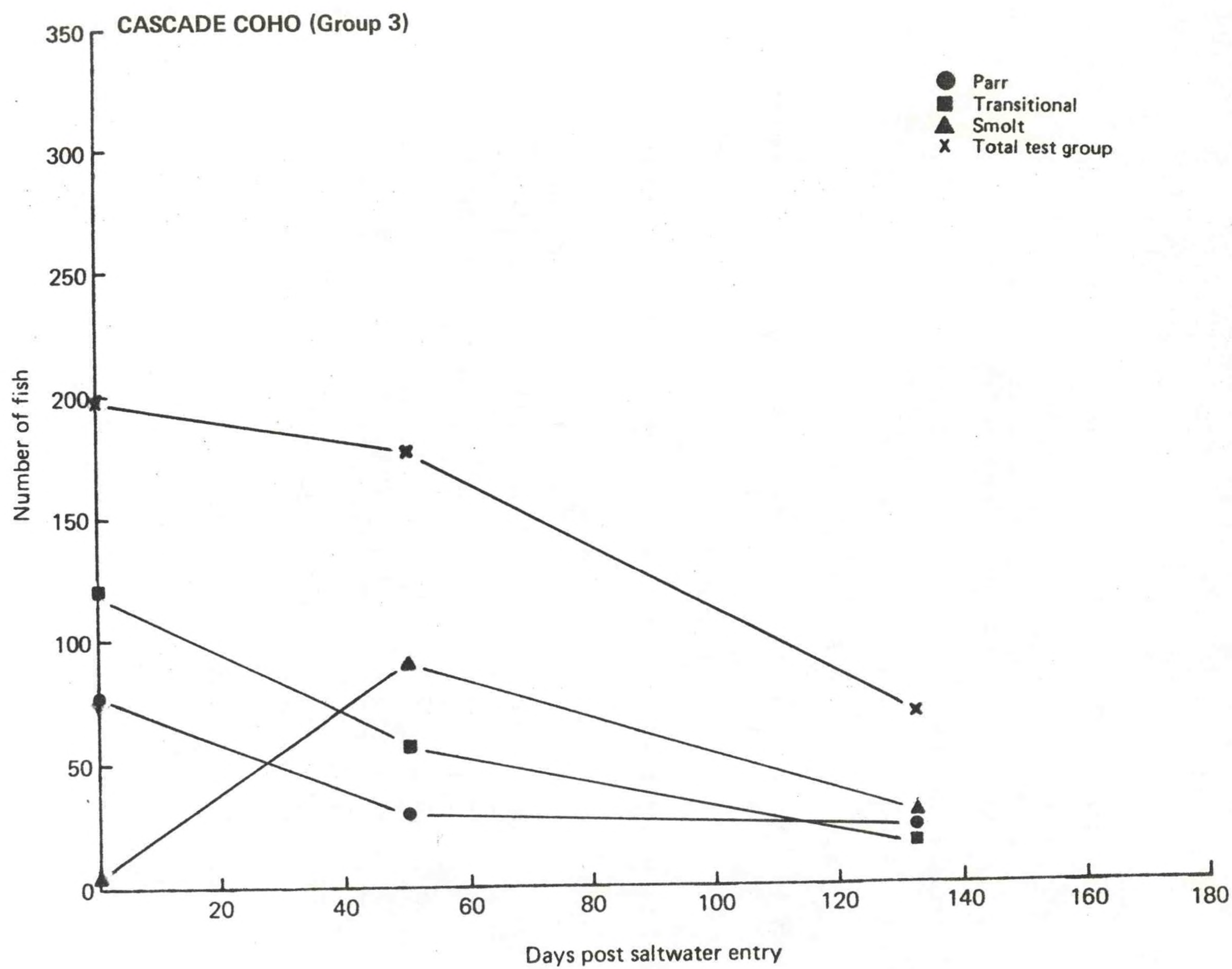


Figure 13.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle (Group 3) Species: Coho Stock: Green River

Date of Initial Observation: 07-09-79 Termination Date: 11-14-79 Elapsed Days: 128

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 68

Surface Water Temperature at Time of Saltwater entry: 11.2°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 ‰ Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.04 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.2 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	40	18	20.0	26.5	19.7	40.6	125.3	161.6
Transitional	150	16	75.0	23.5	24.8	58.8	136.8	178.9
Smolt	10	34	5.0	50.0	32.4	72.5	149.7	190.2
Precocious	0	0	0.0	0.0				
Population	200	68	100.0	100.0	24.2	60.8	135.2	180.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 13 Figure(s): 14

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, 75% of the test group were visually characterized as transitional stage, 20% as parr, and only 5% as smolted fish. After 51 days, 85% of the remaining fish had assumed the appearance of smolted fish. However, at the termination of seawater testing (128 days) reversion to a non-smolted state had occurred leaving only 50% of the fish being characterized as smolts.

Vibrio anguillarum was the bacterial pathogen most frequently isolated from dead fish, with Strain 775 being predominant. The mortality rate increased dramatically after approximately 80 days. Most of the fish dying after this time were much smaller than the mean size for the entire test group, and we interpret this to be symptomatic of long-term osmoregulatory stress. As a result of long-term osmoregulatory difficulties, overall mortality at the time of termination was 66%.

No precocious males were observed in this test group.

TABLE 13.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Group 3	Coho	07-09-79		length[a] weight[b] number	125.3 ± 7.653[c] 19.7 ± 4.260 40	136.8 ± 6.761 24.8 ± 4.010 150	149.7 ± 6.767. 32.4 ± 4.662 10	0	135.2 ± 8.949 24.2 ± 4.942 200
		08-29-79	51	length weight number	131.3 ± 8.238 17.7 ± 2.748 6	140.8 ± 7.169 24.5 ± 4.710 16	156.8 ± 10.465 37.7 ± 9.055 124	0	154.0 ± 12.167 35.4 ± 10.125 146
		11-14-79	77	length weight number	161.6 ± 9.562 40.6 ± 8.474 18	178.9 ± 9.113 58.8 ± 11.144 16	190.2 ± 14.499 72.5 ± 15.063 34	0	180.0 ± 17.026 60.8 ± 18.386 68

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

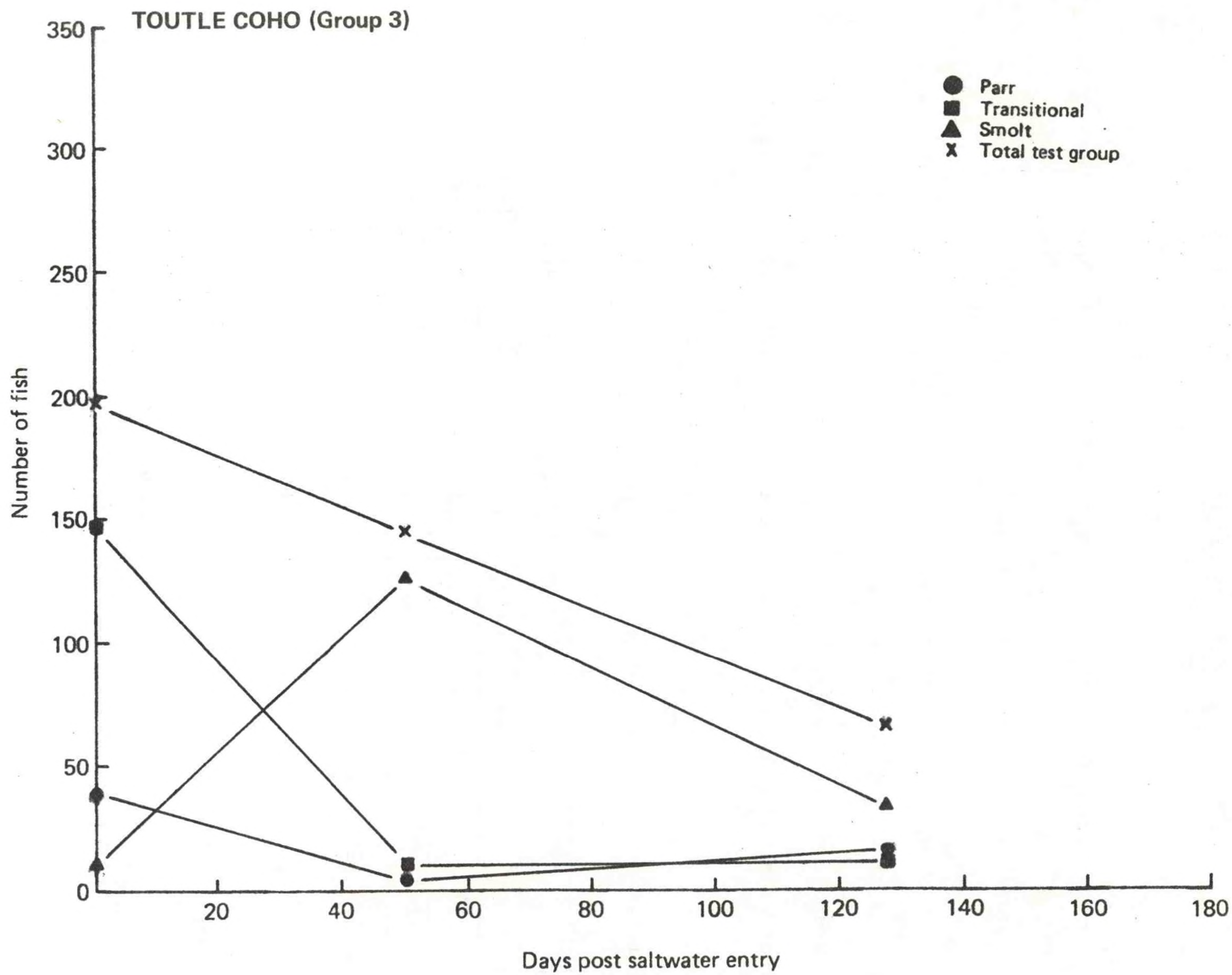


Figure 14.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Washougal (Group 3) Species: Coho Stock: Cowlitz

Date of Initial Observation: 07-09-79 Termination Date: 11-19-79 Elapsed Days: 133

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 64

Surface Water Temperature at Time of Saltwater entry: 11.2°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.04 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.2 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\bar{X}$ (Wt) (g)		$\bar{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	38	12	19.0	18.8	14.8	33.8	114.7	150.8
Transitional	128	13	64.0	20.3	22.3	44.7	132.4	166.8
Smolt	34	39	17.0	60.9	27.6	64.2	143.2	185.9
Precocious	0	0	0.0	0.0				
Population	200	64	100.0	100.0	21.8	54.6	130.9	175.4

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 14 Figure(s): 15

OVERALL SEAWATER ADAPTATION

COMMENTS:

At the time of entry to seawater, only 17% of this test group had the external appearance of smolted fish. By the first measurement (51 days), 77% of those fish remaining had the usual characteristics of smolts. However, by termination (133 days), reversions to a parr state left only 61% smolted.

The mortality rate showed a marked increase after approximately 80 days of seawater exposure. *Vibrio* was isolated in dead fish, but because the majority of dead fish were much smaller than the test group mean, long-term osmoregulatory dysfunction was likely a major factor influencing the mortality rate. Overall mortality for the 133 days of seawater residence was 68%.

No precocious males were observed in this test group.

TABLE 14.--Length and weight of fish during different stages of development in salt water

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Washougal Group 3	Coho	07-09-79		length[a] weight[b] number	114.7 ± 10.208[c] 14.8 ± 3.459 38	132.4 ± 8.370 22.3 ± 4.048 128	143.2 ± 5.500 27.6 ± 3.868 34	0	130.9 ± 12.109 21.8 ± 5.527 200
		08-29-79	51	length weight number	123.7 ± 6.837 18.2 ± 4.697 9	136.6 ± 8.194 22.9 ± 4.649 28	149.6 ± 10.571 33.0 ± 7.850 122	0	145.8 ± 12.381 30.4 ± 8.693 159
		11-19-79	82	length weight number	150.8 ± 8.925 33.8 ± 7.840 12	166.8 ± 7.167 44.7 ± 8.861 13	185.9 ± 14.210 64.2 ± 17.378 39	0	175.4 ± 18.551 54.6 ± 19.182 64

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

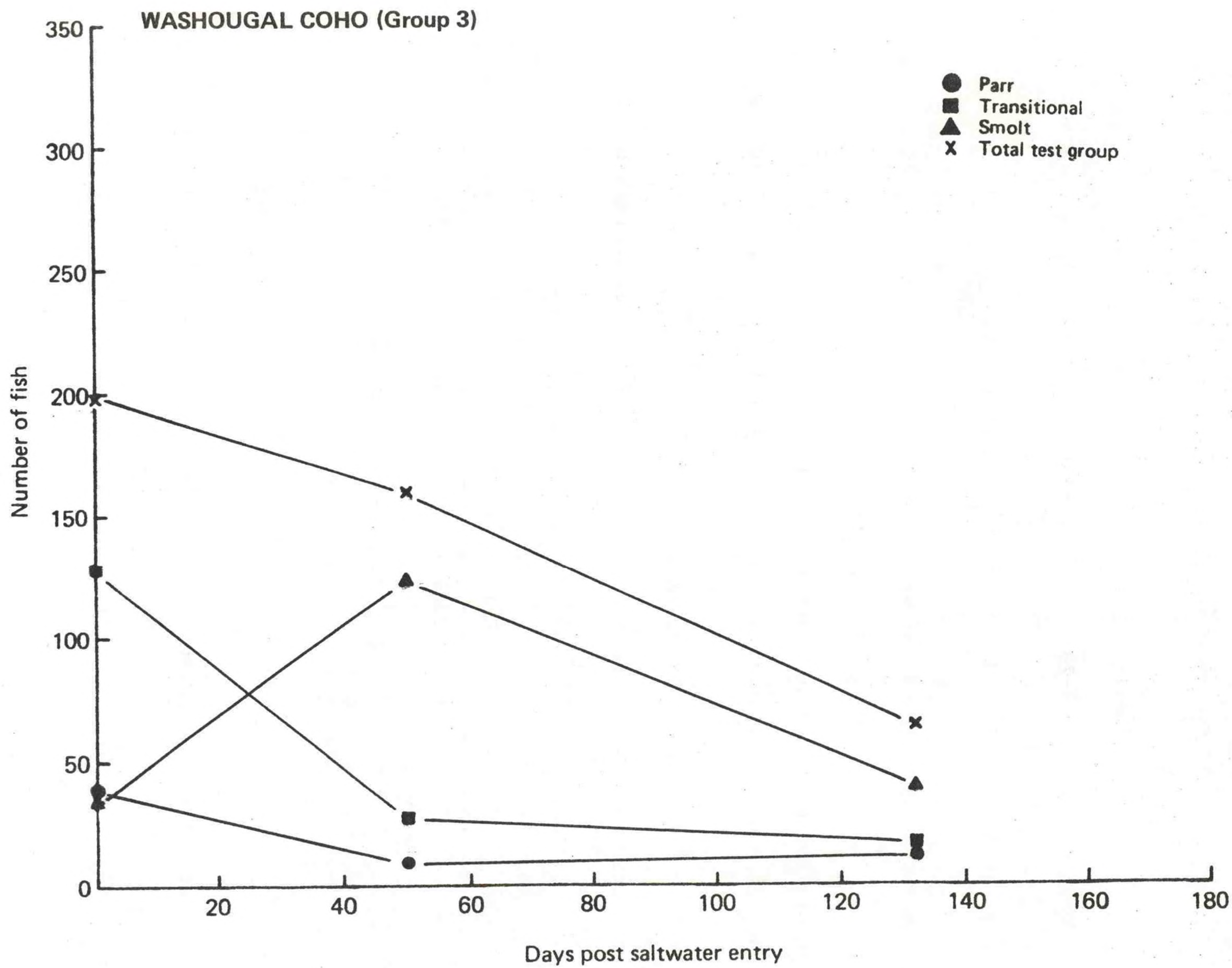


Figure 15.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle   Species: Coho   Stock: Green River (Baseline 1)

Date of Initial Observation: 03-19-79   Termination Date: 11-05-79   Elapsed Days: 231

Number of Replicates: 1   Total No. of Fish at Start: 150
Total No. of Fish at Termination: 47

Surface Water Temperature at Time of Saltwater entry: 7.7°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.61 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.3   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	82	1	54.7	2.1	25.3	43.6	130.2	161.0
Transitional	67	5	44.7	10.6	34.7	65.0	144.9	185.0
Smolt	1	41	0.7	87.2	55.8	107.3	171.0	213.4
Precocious	0	0	0.0	0.0				
Population	150	47	100.0	100.0	29.7	101.5	137.0	209.2

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 15   Figure(s): 16

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, all fish had the external appearance of parr or transitional stage fish. By approximately 90 days after seawater entry more than 85% of the fish had successfully smolted. The fish remained in a smolted state for the duration of the study (231 days).

No major problems associated with osmoregulatory dysfunction were observed in this test group.

Mortality from *Vibrio anguillarum* was most severe after approximately 120 days. Overall mortality was 69%.

TABLE 15.--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 01	Coho	03-19-79		length[a/] weight[b/] number	130.2 ± 10.471[c/] 25.3 ± 5.730 82	144.9 ± 8.095 34.7 ± 6.131 67	171.0 ± 0.000 55.8 ± 0.000 1	0	137.0 ± 12.225 29.7 ± 7.818 150
		06-14-79	87	length weight number	0	134.4 ± 7.632 24.3 ± 7.482 11	154.9 ± 9.483 38.5 ± 7.819 116	0	153.1 ± 10.963 37.2 ± 8.730 127
		07-24-79	40	length weight number	33.3 ± 9.292 18.6 ± 1.457 3	149.4 ± 8.998 33.0 ± 9.241 15	162.7 ± 10.665 46.2 ± 10.236 100	0	160.3 ± 12.097 43.8 ± 11.617 118
		08-30-79	37	length weight number	144.5 ± 2.121 28.3 ± 1.838 2	151.5 ± 8.873 34.6 ± 8.663 10	175.2 ± 12.031 61.8 ± 14.8 83	0	172.1 ± 14.230 58.3 ± 16.948 95
		11-05-79	67	length weight number	161.0 ± 0.000 43.6 ± 0.000 1	185.0 ± 13.323 65.0 ± 14.983 5	213.4 ± 16.620 107.3 ± 28.548 41	0	209.2 ± 19.628 101.5 ± 31.243 41

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

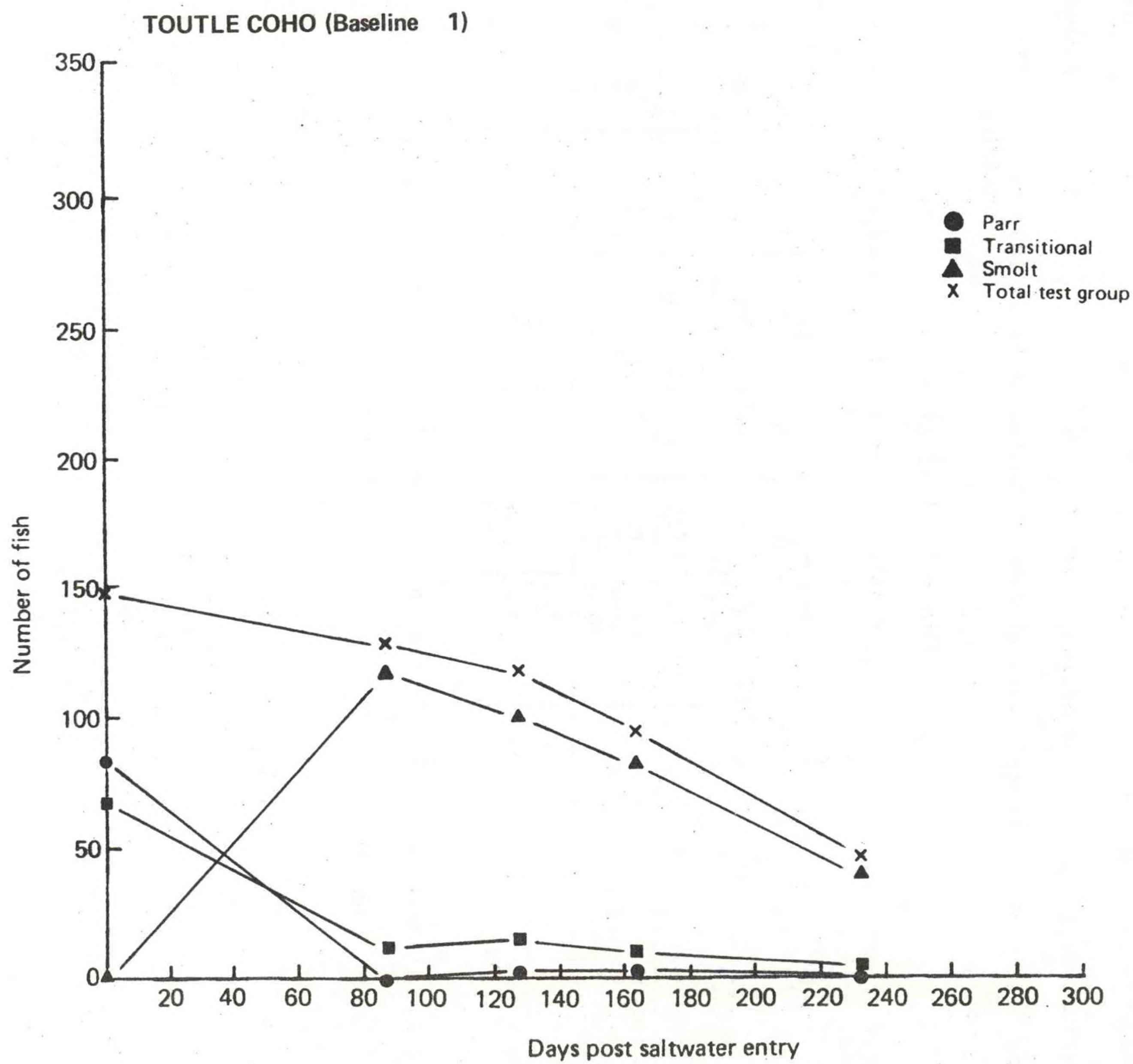


Figure 16.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle   Species: Coho   Stock: Green River (Baseline 2)

Date of Initial Observation: 04-02-79   Termination Date: 11-05-79   Elapsed Days: 217

Number of Replicates: 1   Total No. of Fish at Start: 150
Total No. of Fish at Termination: 33

Surface Water Temperature at Time of Saltwater entry: 7.6°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.42 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	13	2	8.7	6.1	20.0	54.0	123.2	172.5
Transitional	122	7	81.3	21.2	30.5	55.9	140.6	178.0
Smolt	15	24	10.0	72.7	41.6	117.8	157.0	221.4
Precocious	0	0	0.0	0.0				
Population	150	33	100.0	100.0	30.7	100.8	140.7	209.2

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 16   Figure(s): 17

OVERALL SEAWATER ADAPTATION

COMMENTS

Only 10% of the test group had the usual appearance of smolts when transferred to seawater. However, after 73 days, over 90% appeared to be smolts. Thereafter, reversions occurred at a low level. At the time of termination (217 days), 73% of the fish remaining were smolted.

Overall mortality in this test group was 78%. Mortality was primarily from *Vibrio anguillarum*.

No precocious males were observed in this test group.

TABLE 16.--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Toutle	Coho	04-02-79		length[a]	123.2 ± 16.175[c]	140.6 ± 9.975	157.0 ± 14.471		140.7 ± 13.235
Baseline 02				weight[b]	20.0 ± 8.081	30.5 ± 6.816	41.6 ± 13.967		30.7 ± 9.125
				number	13	122	15	0	150
		06-14-79	73	length	98.0 ± 0.000	139.7 ± 8.817	155.9 ± 9.973		154.4 ± 11.694
				weight	10.5 ± 0.000	25.8 ± 5.608	39.9 ± 8.720		38.7 ± 9.511
				number	1	9	126	0	136
		07-24-79	40	length	131.4 ± 11.858	146.8 ± 8.431	166.2 ± 10.811		161.6 ± 14.415
				weight	19.2 ± 4.215	29.8 ± 6.464	49.6 ± 10.759		45.2 ± 13.631
				number	7	18	104	0	129
		08-30-79	37	length	136.8 ± 6.760	153.8 ± 9.026	175.6 ± 12.645		171.6 ± 15.763
				weight	22.3 ± 3.798	35.7 ± 5.641	61.1 ± 15.296		56.6 ± 17.871
				number	5	12	95	0	112
		11-05-79	67	length	172.5 ± 7.778	178.0 ± 11.416	221.4 ± 13.815		209.2 ± 23.912
				weight	54.0 ± 10.677	55.9 ± 9.798	117.8 ± 27.269		100.8 ± 36.7
				number	2	7	24	0	33

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

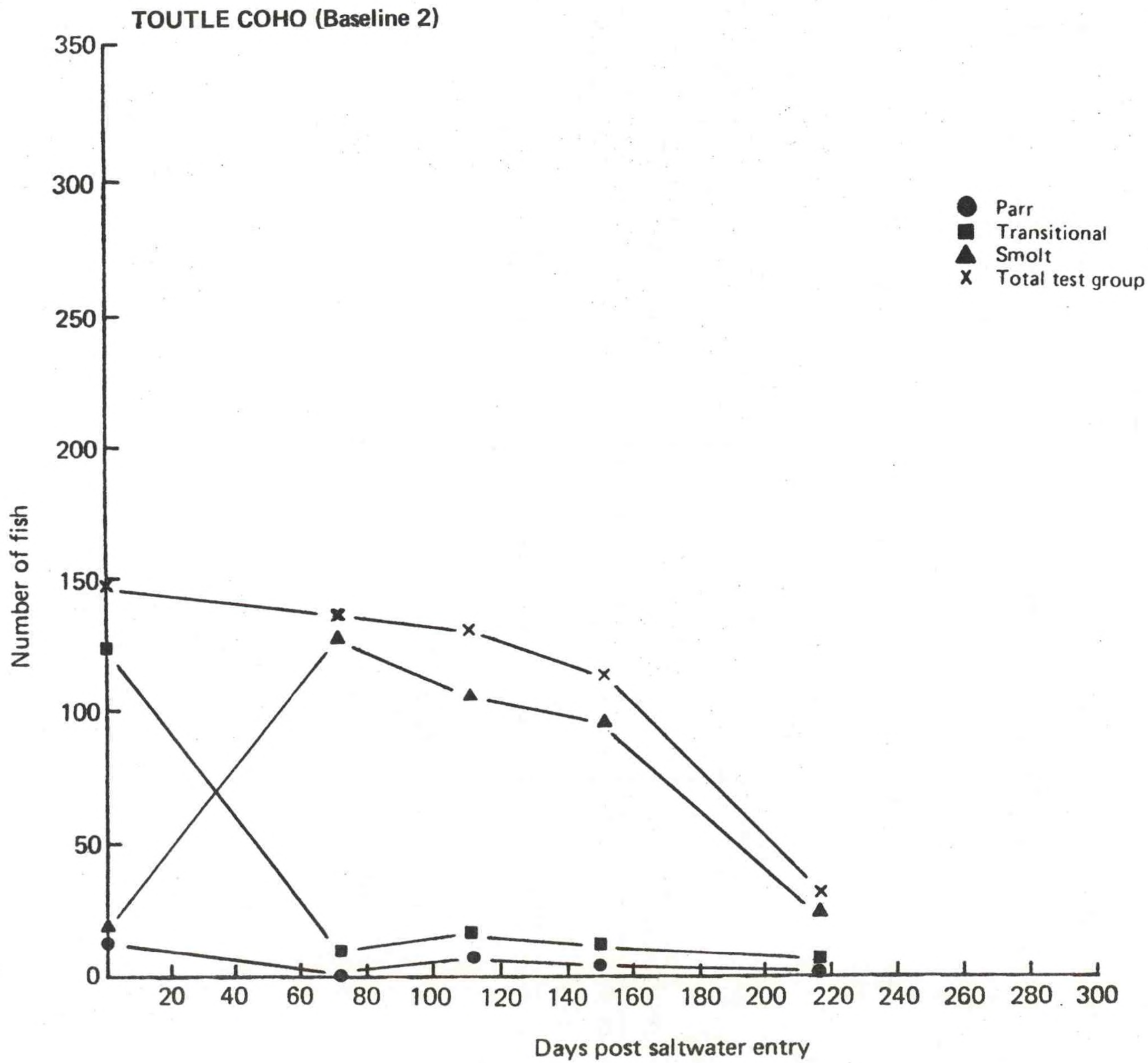


Figure 17.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle　　Species: Coho　　Stock: Green River (Baseline 3)

Date of Initial Observation: 04-16-79　　Termination Date: 11-05-79　　Elapsed Days: 203

Number of Replicates: 1　　Total No. of Fish at Start: 150
Total No. of Fish at Termination: 51

Surface Water Temperature at Time of Saltwater entry: 7.8°C　　Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.5 °/oo　　Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.56 ppm　　Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.7　　Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	9	2	6.0	3.9	20.8	33.8	121.6	156.0
Transitional	106	6	70.7	11.8	33.0	53.7	144.0	181.5
Smolt	35	43	23.3	84.3	43.8	106.6	157.2	212.9
Precocious	0	0	0.0	0.0				
Population	150	51	100.0	100.0	34.8	97.5	145.7	207.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 17　　Figure(s): 18

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of introduction to seawater, only 23% of the fish were visually characterized as smolts; however, after 60 days, 96% appeared to be smolts. Reversions to a non-smolted condition occurred at low levels.

The mortality rate showed a marked increase after approximately 120 days, mainly due to infection with *Vibrio anguillarum*, as the protection provided by the vaccine/antibiotic solution diminished. Overall mortality was 66%.

No precocious males were observed in this test group.

TABLE 17.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 03	Coho	04-16-79		length[a/] weight[b/] number	121.6 ± 8.530[c/] 20.8 ± 4.714 9	144.0 ± 8.291 33.0 ± 5.625 106	157.3 ± 7.705 43.8 ± 7.189 35	0	145.7 ± 11.600 34.8 ± 8.278 150
		06-14-79	59	length weight number	124.0 ± 0.000 14.2 ± 0.000 1	140.4 ± 5.856 27.6 ± 2.644 5	158.1 ± 9.381 42.9 ± 8.367 142	0	157.3 ± 10.162 42.2 ± 8.971 148
		07-24-79	40	length weight number	131.0 ± 0.000 22.5 ± 0.000 1	148.6 ± 6.438 30.6 ± 4.329 16	167.3 ± 10.102 49.6 ± 10.392 113	0	164.7 ± 11.836 47.0 ± 11.816 130
		08-30-79	37	length weight number	0 0 0	157.7 ± 12.952 38.3 ± 10.096 9	176.9 ± 11.873 62.9 ± 14.370 99	0	175.3 ± 13.043 60.8 ± 15.592 108
		11-05-79	67	length weight number	156.0 ± 14.142 33.8 ± 6.223 2	181.5 ± 4.806 53.7 ± 6.502 6	212.9 ± 16.963 106.6 ± 30.084 43	0	207.0 ± 21.450 97.5 ± 35.041 51

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

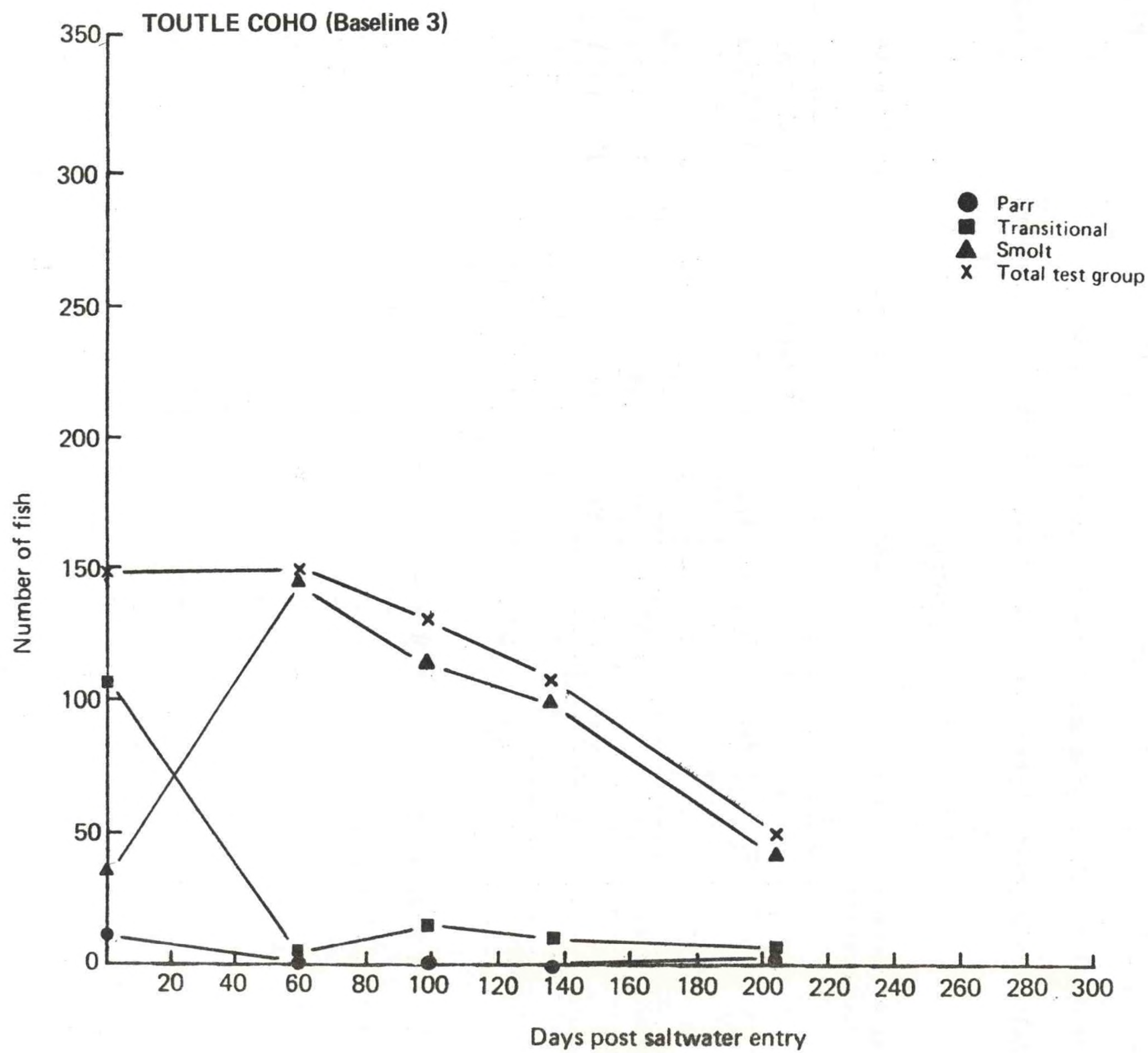


Figure 18.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle Species: Coho Stock: Green River (Baseline 4)

Date of Initial Observation: 04-30-79 Termination Date: 11-05-79 Elapsed Days: 189

Number of Replicates: 1 Total No. of Fish at Start: 150
Total No. of Fish at Termination: 56

Surface Water Temperature at Time of Saltwater entry: 8.8°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 30.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.03 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.3 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	0	1	0	1.8	0	49.1	0	164.0
Transitional	109	4	72.7	7.1	34.8	61.2	146.8	184.8
Smolt	41	50	27.3	89.3	47.0	102.3	162.8	211.7
Precocious	0	1	0	1.8	0	80.7	0	198.0
Population	150	56	100.0	100.0	38.2	98.0	151.2	208.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 18 Figure(s): 19

OVERALL SEAWATER ADAPTATION

COMMENTS

More than 78% of the test was visually characterized as transitional stage fish at the time of introduction to seawater. After 46 days, 99% of the fish had assumed the appearance of smolted fish. Subsequent reversions to a nonsmolted condition were minimal.

The mortality rate increased after 122 days, so that by termination (189 days) overall mortality was 63%.

No precocious males were observed in this test group.

TABLE 18.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle	Coho	04-30-79		length[a/]		146.8 ± 10.438[c/]	162.8 ± 8.662		151.2 ± 12.266
				weight[b/]		34.8 ± 7.364	47.0 ± 8.382		38.2 ± 9.386
Baseline 04				number	0	109	27	0	150
		06-15-79	46	length		142.5 ± 0.707	160.2 ± 10.584		159.9 ± 10.709
				weight		29.9 ± 2.545	44.2 ± 8.674		44.0 ± 8.775
				number	0	2	99	0	148
		07-25-79	86	length	144.7 ± 12.220	152.5 ± 10.985	168.0 ± 11.219		166.3 ± 12.306
				weight	25.4 ± 1.900	35.4 ± 6.728	50.6 ± 10.632		48.9 ± 11.564
				number	3	11	90	0	143
		08-30-79	122	length	145.0 ± 9.466	153.8 ± 10.478	176.3 ± 12.939		172.7 ± 15.398
				weight	30.9 ± 10.914	37.2 ± 8.628	62.0 ± 16.339		58.2 ± 18.142
				number	6	12	86	0	129
		11-05-79	67	length	164.0 ± 0.000	184.8 ± 5.852	211.7 ± 14.655	198.0 ± 0.000	208.6 ± 16.772
				weight	49.1 ± 0.000	61.2 ± 6.189	102.3 ± 22.853	80.7 ± 0.000	98.0 ± 25.127
				number	1	4	89	1	37

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

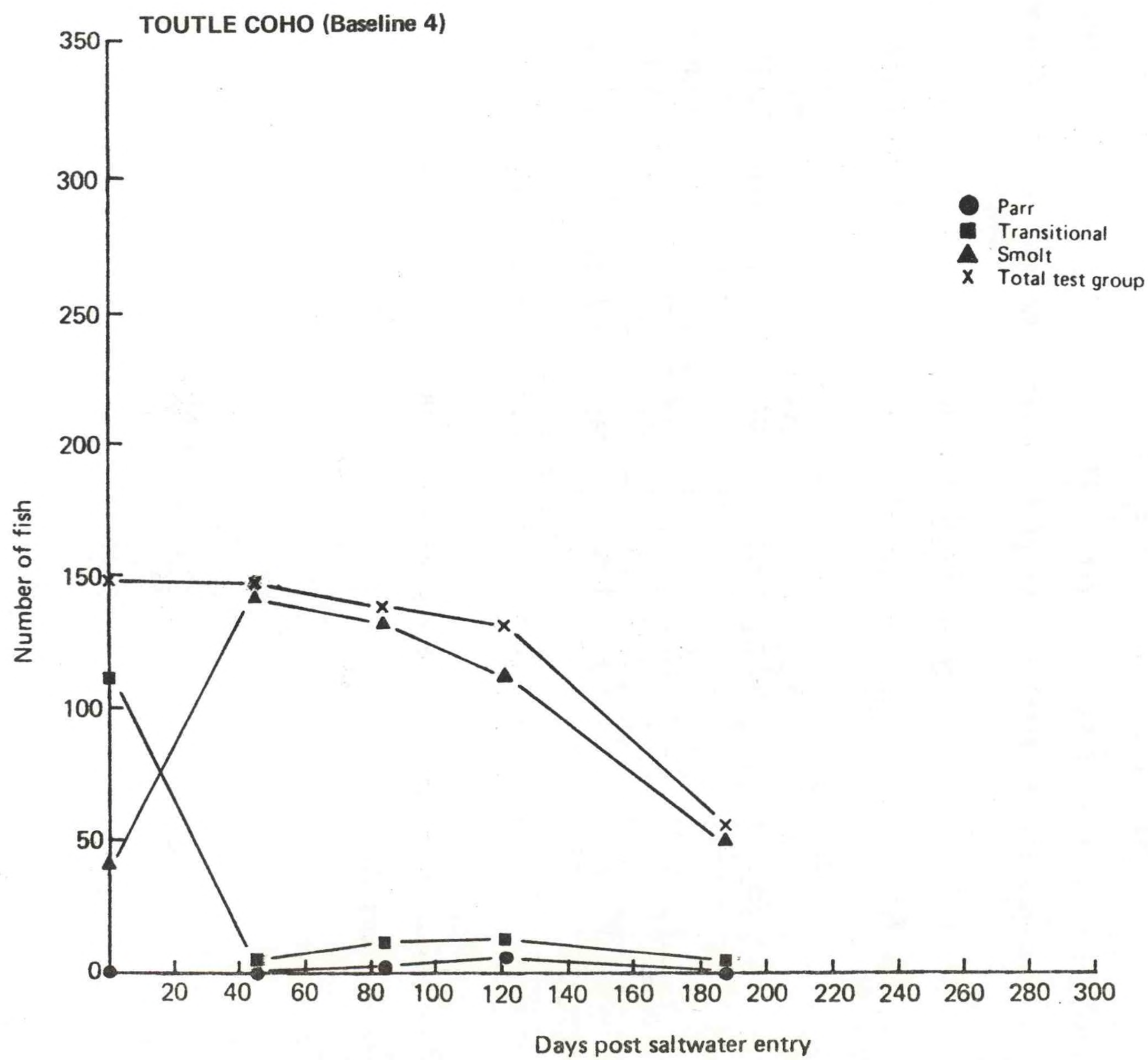


Figure 19.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle Species: Coho Stock: Green River (Baseline 5)

Date of Initial Observation: 05-14-79 Termination Date: 11-13-79 Elapsed Days: 183

Number of Replicates: 1 Total No. of Fish at Start: 149
Total No. of Fish at Termination: 62

Surface Water Temperature at Time of Saltwater entry: 10.2°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 12.69 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 2.4 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	0	2	0.0	3.2		4.1		163.0
Transitional	19	4	12.8	6.5	31.1	59.4	141.8	178.3
Smolt	130	56	87.2	90.3	43.4	115.0	157.7	218.0
Precocious	0	0	0.0	0.0				
Population	149	62	100.0	100.0	41.8	109.1	155.7	213.7

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 19 Figure(s): 20

OVERALL SEAWATER ADAPTATION

COMMENTS

This group of fish entered seawater near peak of smoltification as determined by biochemical and external characteristics. At seawater entry, 87% of the fish in this group were smolted, and within 32 days, 99% were classified as smolts based on external criteria. In spite of the large number of smolts at seawater entry, this group did not perform well in seawater. We believe the poor performance was from disease problems (primarily furunculosis) encountered during freshwater rearing. The disease problems weakened the fish thus making them more susceptible to Vibrio anguillarum and other marine pathogens in the early period of seawater residence.

Overall mortality was 58%. Baseline groups four and six did not show initial high mortality rates.

TABLE 19.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 05	Coho	05-14-79		length[a/] weight[b/] number	 0	141.8 ± 8.810[c/] 31.1 ± 5.424 19	157.7 ± 9.501 43.4 ± 8.473 130	 0	155.7 ± 10.797 41.8 ± 9.105 149
		06-15-79	32	length weight number	 0	145.0 ± 0.000 34.1 ± 0.000 1	162.3 ± 9.769 43.9 ± 8.392 138	 0	162.1 ± 9.843 43.8 ± 8.403 139
		07-25-79	40	length weight number	138.0 ± 0.000 26.6 ± 0.000 1	154.7 ± 5.676 35.1 ± 6.992 11	171.1 ± 10.247 53.4 ± 11.080 122	 0	169.5 ± 11.214 51.7 ± 12.063 134
		08-30-79	36	length weight number	159.3 ± 6.602 34.9 ± 8.049 4	160.6 ± 6.041 39.3 ± 6.380 10	181.8 ± 12.371 67.6 ± 16.751 102	 0	179.2 ± 13.724 64.0 ± 18.582 116
		11-13-79	75	length weight number	163.0 ± 1.414 41.0 ± 4.031 4	178.3 ± 13.426 59.4 ± 20.509 4	218.0 ± 18.414 115.0 ± 33.857 56	 0	213.7 ± 22.319 109.1 ± 37.431 62

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

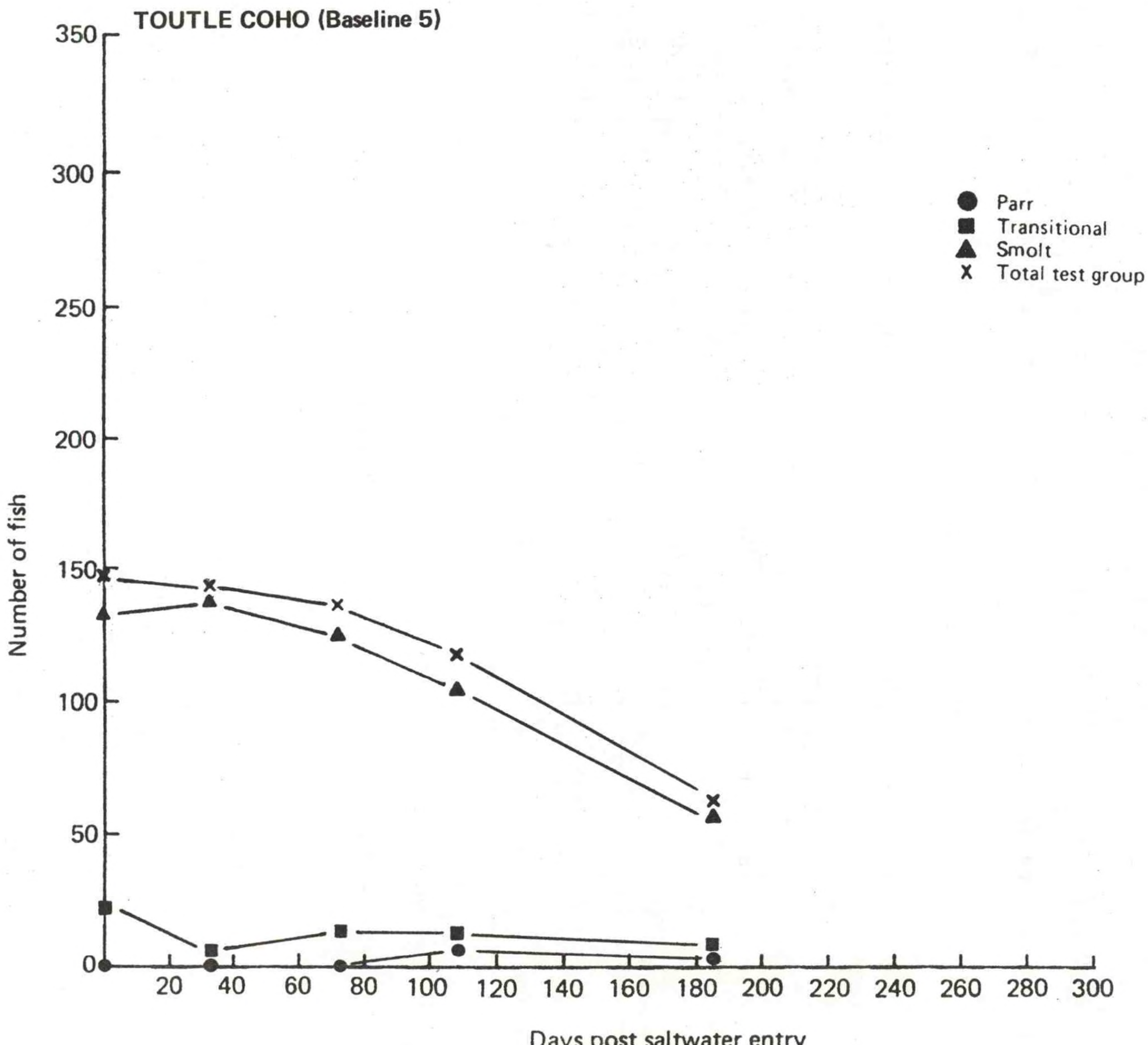


Figure 20.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle | Species: Coho | Stock: Green River (Baseline 6)

Date of Initial Observation: 05-29-79 | Termination Date: 11-13-79 | Elapsed Days: 168

Number of Replicates: 1 | Total No. of Fish at Start: 150
Total No. of Fish at Termination: 57

Surface Water Temperature at Time of Saltwater entry: 10.0°C | Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo | Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.38 ppm | Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 6.0 | Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	0	1	0.0	1.8		37.8		171.0
Transitional	34	8	22.7	14.0	33.2	64.5	145.8	185.0
Smolt	116	48	77.3	84.2	47.9	110.3	162.2	214.4
Precocious	0	0	0.0	0.0				
Population	150	57	100.0	100.0	44.6	102.6	158.8	209.5

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 20 | Figure(s): 21

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, 77% of this test group was visually characterized as smolted fish. This figure increased to 95% after 57 days and remained above 92% thereafter. There were no mortalities directly associated with osmoregulatory dysfunction.

Overall mortality was only 10% after 93 days, but due to infection by *Vibrio anguillarum*, this figure had increased to 62% by the time of termination (168 days).

No precocious males were observed in this test group.

TABLE 20.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 06	Coho	05-29-79		length[a/]		145.8 ± 10.109[c/]	162.6 ± 9.672		158.8 ± 12.028
				weight[b/]		33.2 ± 6.657	47.9 ± 9.673		44.6 ± 10.963
				number	0	34	116	0	150
		07-25-79	57	length	132.0 ± 14.142	147.3 ± 6.946	170.3 ± 11.071		169.2 ± 12.372
				weight	22.8 ± 9.617	30.6 ± 2.760	54.0 ± 11.911		53.0 ± 12.808
				number	2	4	142	0	148
		08-30-79	36	length		157.9 ± 7.595	179.2 ± 12.601		177.4 ± 13.568
				weight		39.6 ± 6.169	63.2 ± 15.748		61.3 ± 16.515
				number	0	11	124	0	135
		11-13-79	75	length	171.0 ± 0.000	185.0 ± 9.607	214.4 ± 19.188		209.5 ± 21.283
				weight	37.8 ± 0.000	64.5 ± 16.431	110.3 ± 34.671		102.6 ± 37.092
				number	1	8	48	0	57

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

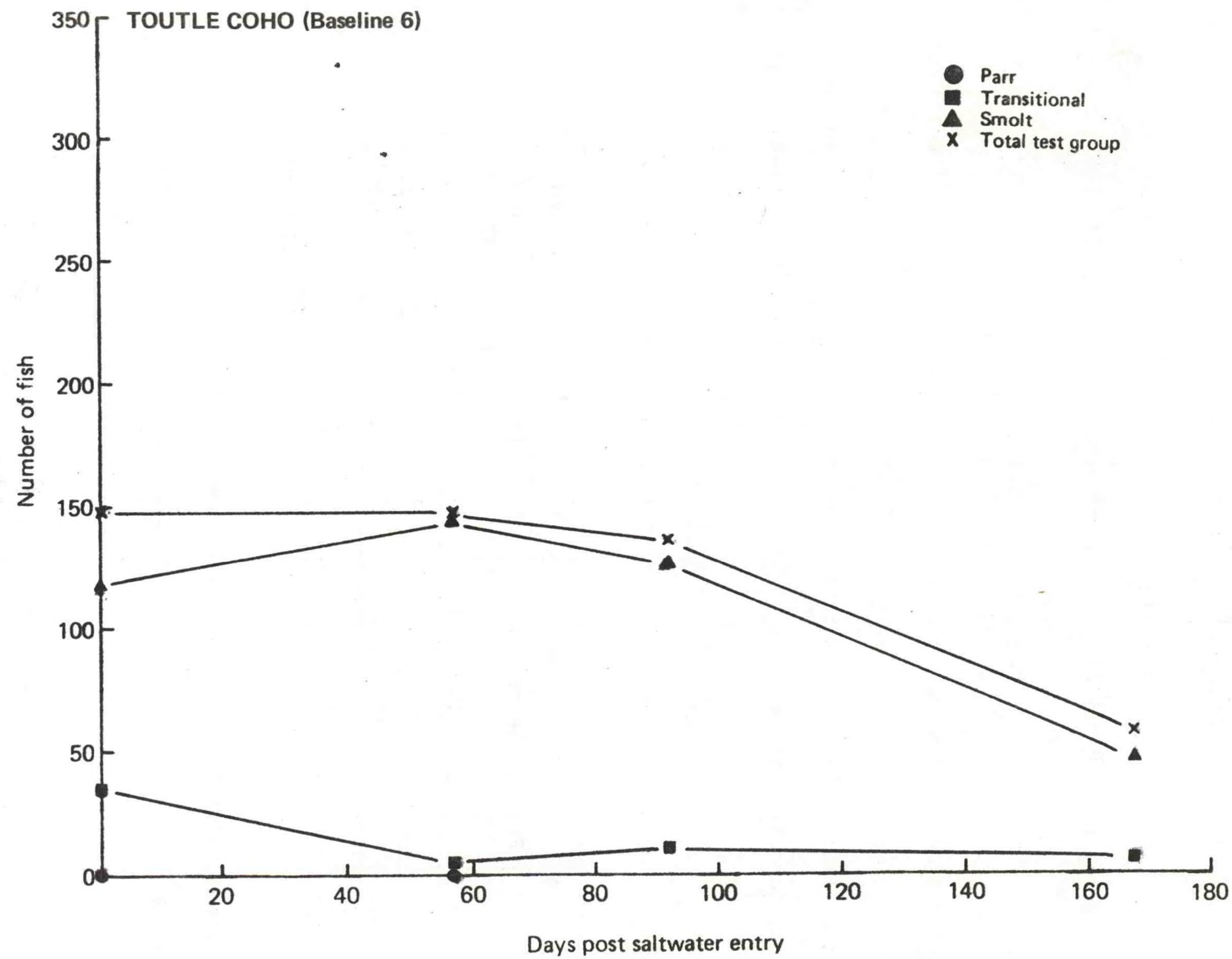


Figure 21.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle Species: Coho Stock: Green River (Baseline 7)

Date of Initial Observation: 06-11-79 Termination Date: 11-13-79 Elapsed Days: 155

Number of Replicates: 1 Total No. of Fish at Start: 150
Total No. of Fish at Termination: 63

Surface Water Temperature at Time of Saltwater entry: 11.8°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 10.47 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 3.3 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	0	2	0.0	3.2		49.4		172.0
Transitional	16	8	10.7	12.7	36.4	59.7	148.2	182.5
Smolt	134	53	89.3	84.1	52.4	109.5	165.8	216.0
Precocious	0	0	0.0	0.0				
Population	150	63	100.0	100.0	50.7	101.3	163.9	210.4

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 21 Figure(s): 22

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of entry to seawater, 89% of this test group had the external appearance of smolts and the percentage of smolts was maintained above 84% for the duration of observation (155 days). No immediate losses due to osmoregulatory stress were observed.

Overall mortality was only 10% after 80 days, but subsequently increased greatly so that by 155 days (termination) this figure had reached 58%.

No precocious males were observed in this test group.

TABLE 21.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 07	Coho	06-11-79		length[a/]		148.3 ± 10.056[c/]	165.8 ± 10.858		163.9 ± 12.041
				weight[b/]		36.4 ± 7.865	52.4 ± 11.024		50.7 ± 11.801
				number	0	16	89	0	150
		07-25-79	44	length		143.0 ± 0.000	175.2 ± 11.950		175.0 ± 12.214
				weight		28.2 ± 0.000	60.5 ± 13.568		60.3 ± 13.792
				number	0	1	99	0	140
		08-31-79	80	length	148.0 ± 0.000	159.3 ± 9.247	183.8 ± 12.701		181.9 ± 14.164
				weight	24.5 ± 0.000	39.7 ± 8.883	68.4 ± 16.030		66.2 ± 17.530
				number	1	9	93	0	90
		11-13-79	154	length	172.0 ± 5.657	182.5 ± 8.106	216.0 ± 15.538		210.4 ± 19.637
				weight	49.4 ± 10.748	59.7 ± 13.217	109.5 ± 26.314		101.3 ± 31.149
				number	2	8	84	0	42

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

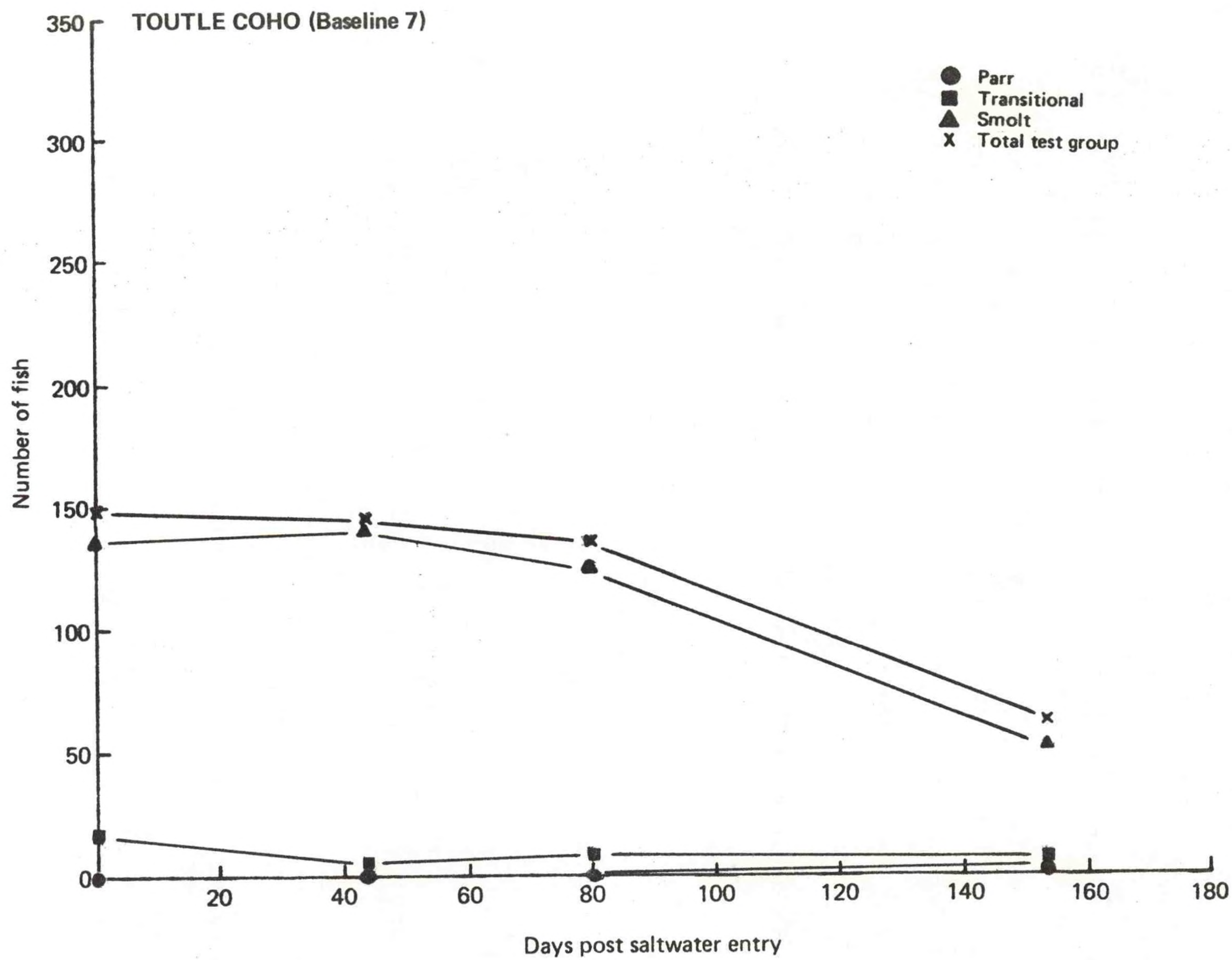


Figure 22.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: **Toutle** Species: **Coho** Stock: **Green River (Baseline 8)**

Date of Initial Observation: **07-23-79** Termination Date: **11-13-79** Elapsed Days: **113**

Number of Replicates: **1** Total No. of Fish at Start: **150**
Total No. of Fish at Termination: **85**

Surface Water Temperature at Time of Saltwater entry: 12.6°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.00 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 6.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	2	2	1.3	2.4	33.7	39.7	138.0	175.5
Transitional	81	12	54.0	14.1	62.5	58.6	172.5	186.3
Smolt	67	71	44.7	83.5	77.4	118.8	185.4	222.0
Precocious	0	0	0.0	0.0				
Population	150	85	100.0	100.0	68.8	108.4	177.8	215.9

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 22 Figure(s): 23

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, less than 45% of this test group had the visual appearance of smolts. However, by 39 days, 89% of the fish appeared to be smolts. Reversions to a nonsmolted state subsequently reduced the figure to 83% by the time of termination (113 days). No mortalities associated with osmoregulatory dysfunction were observed in this test group.

Overall mortality was approximately 43%, due mainly to *Vibrio anguillarum* and occurring primarily after 39 days.

TABLE 22.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 08	Coho	07-23-79		length[a/] weight[b/] number	138.0 ± 5.657[c/] 33.7 ± 4.384 2	172.5 ± 11.040 62.5 ± 12.244 81	185.4 ± 10.339 77.4 ± 15.345 67	0	177.8 ± 13.242 68.8 ± 15.997 150
		08-31-79	39	length weight number	0	153.0 ± 0.000 31.6 ± 0.000 1	190.2 ± 13.923 75.5 ± 17.659 135	0	189.9 ± 14.233 75.2 ± 17.993 136
		11-13-79	74	length weight number	175.5 ± 3.536 39.7 ± 0.636 2	186.3 ± 8.181 58.6 ± 9.388 12	222.0 ± 18.138 118.8 ± 35.499 71	0	215.9 ± 21.892 108.4 ± 40.249 85

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

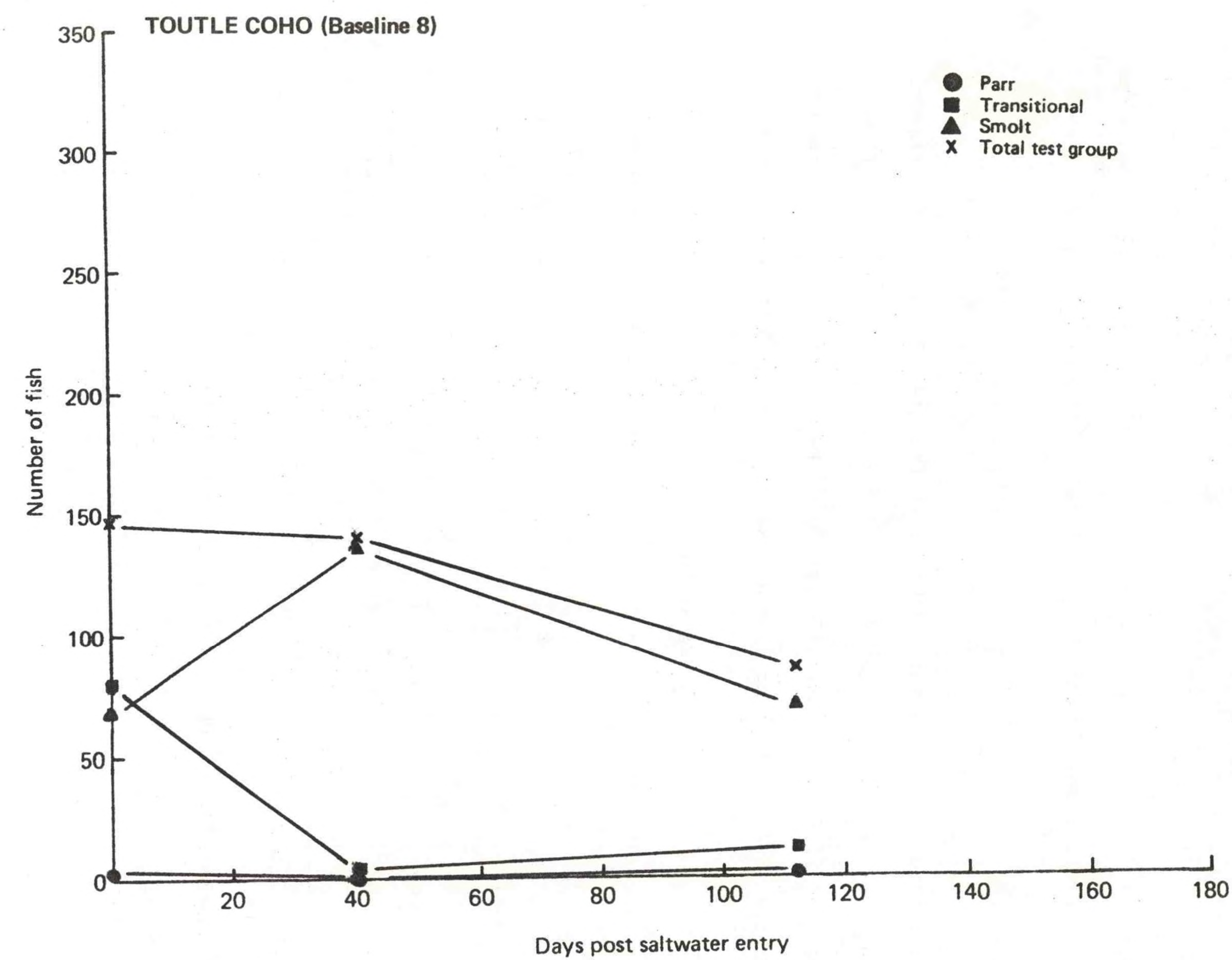


Figure 23.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle

Species: Coho

Stock: Green River (Baseline 9)

Date of Initial Observation: 08-20-79

Termination Date: 11-13-79

Elapsed Days: 85

Number of Replicates: 1

Total No. of Fish at Start: 150

Total No. of Fish at Termination: 86

Surface Water Temperature at Time of Saltwater entry: 13.0°C — Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo — Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 6.35 ppm — Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 3.7 — Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	0	2	0.0	2.3		43.9		179.5
Transitional	97	12	64.7	14.0	76.0	52.7	184.7	180.3
Smolt	53	72	35.3	83.7	90.2	119.5	195.4	222.1
Precocious	0	0	0.0	0.0				
Population	150	86	100.0	100.0	81.0	108.5	188.5	215.3

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 23

Figure(s): 24

OVERALL SEAWATER ADAPTATION

COMMENTS

Only 35% of this test group had the external appearance of smolted fish at the time of entry to seawater. This figure increased to 95% at 35 days and subsequently declined to 83% at the time of termination (85 days) due to reversions to a nonsmolted condition. No direct deaths were attributable to osmoregulatory dysfunction.

Overall mortality was 43%, due mainly to *Vibrio anguillarum*.

One precocious male was observed at 35 days.

TABLE 23.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle Baseline 09	Coho	08-20-79		length[a/]		184.7 ± 12.507[c/]	195.4 ± 11.203		188.5 ± 13.073
				weight[b/]		76.0 ± 16.072	90.2 ± 18.200		81.0 ± 18.121
				number	0	97	53	0	150
		09-24-79	35	length		172.3 ± 10.532	199.4 ± 15.169	172.0 ± 0.000	198.2 ± 15.910
				weight		49.4 ± 8.100	92.0 ± 25.327	63.5 ± 0.000	90.4 ± 26.107
				number	0	4	114	1	119
		11-13-79	50	length	179.5 ± 7.778	180.3 ± 10.697	222.1 ± 18.167		215.3 ± 23.096
				weight	43.9 ± 7.849	52.7 ± 6.329	119.5 ± 37.680		108.5 ± 42.808
				number	2	12	72	0	86

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

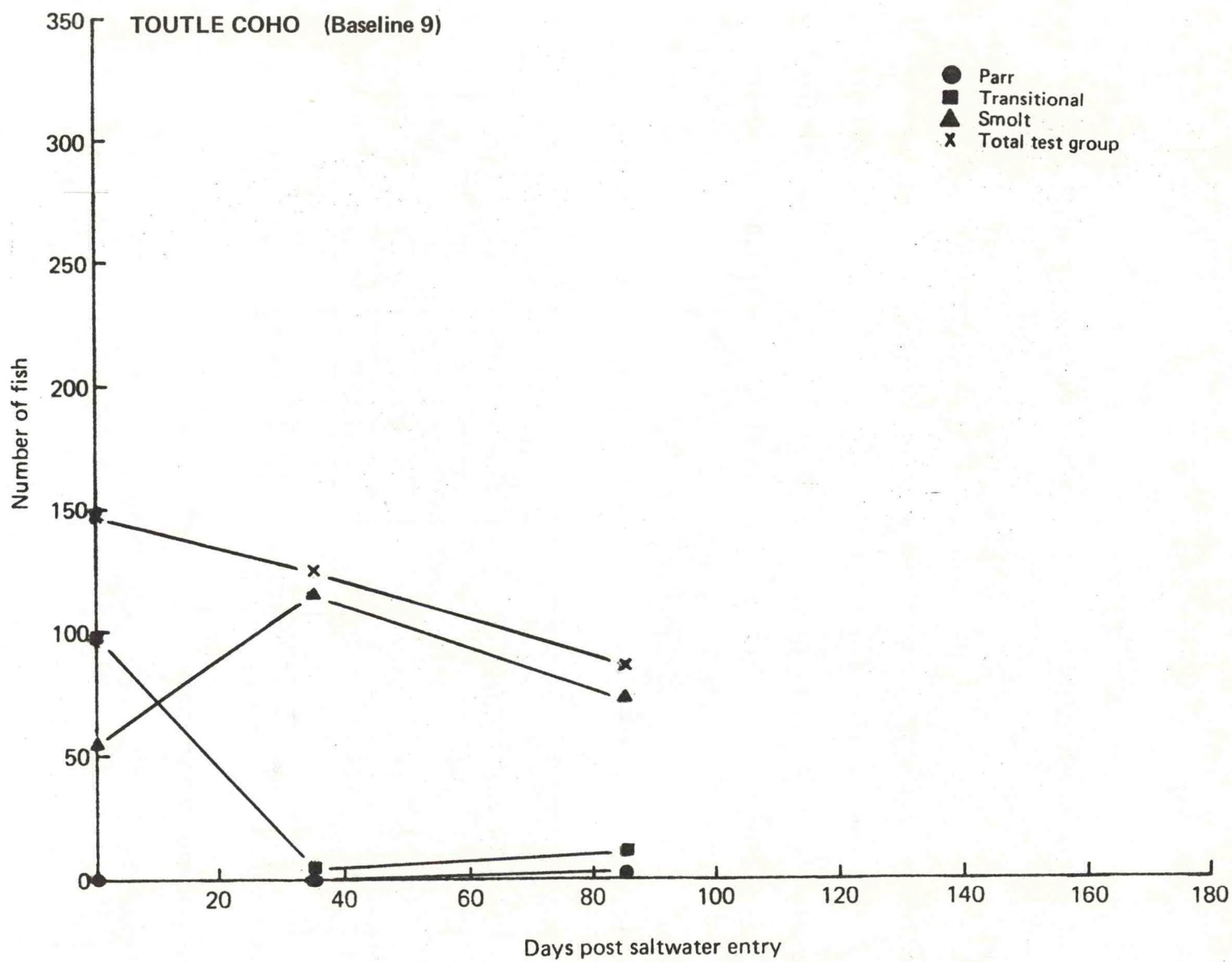


Figure 24.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle   Species: Coho   Stock: Green River (Baseline 10)

Date of Initial Observation: 09-17-79   Termination Date: 11-15-79   Elapsed Days: 59

Number of Replicates: 1   Total No. of Fish at Start: 150
Total No. of Fish at Termination: 139

Surface Water Temperature at Time of Saltwater entry: 12.6^{o}C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 30.0 ^{o}/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 6.85 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.9   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	25	3	16.7	2.2	76.8	60.0	180.1	174.0
Transitional	55	13	36.7	9.4	94.6	61.2	193.3	181.4
Smolt	70	122	46.7	87.8	116.1	115.4	207.1	219.2
Precocious	0	1	0.0	0.7		104.0		198.0
Population	150	139	100.0	100.0	101.7	109.0	197.5	214.5

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 24   Figure(s): 25

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, 47% of these fish had the external appearance of smolts. This figure increased to 87% by the time of termination (59 days). No losses from osmoregulatory dysfunction were observed in this test group.

Overall mortality in this test group was less than 8%, due primarily to the short observation period.

One precocious male was observed in this test group.

TABLE 24.--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Toutle	Coho			length[a]	180.1 ± 8.175[c]	193.3 ± 8.981	207.1 ± 10.601		197.5 ± 13.883
Baseline		09-17-79		weight[b]	76.8 ± 10.539	94.6 ± 13.054	116.1 ± 19.611		101.7 ± 21.861
10				number	25	55	70	0	150
				length	174.0 ± 13.229	181.4 ± 6.702	219.2 ± 17.067	198.0 ± 0.000	214.5 ± 20.543
		11-15-79	59	weight	60.0 ± 15.215	61.2 ± 7.109	115.4 ± 31.167	104.0 ± 0.000	109.0 ± 34.105
				number	3	13	122	1	139

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

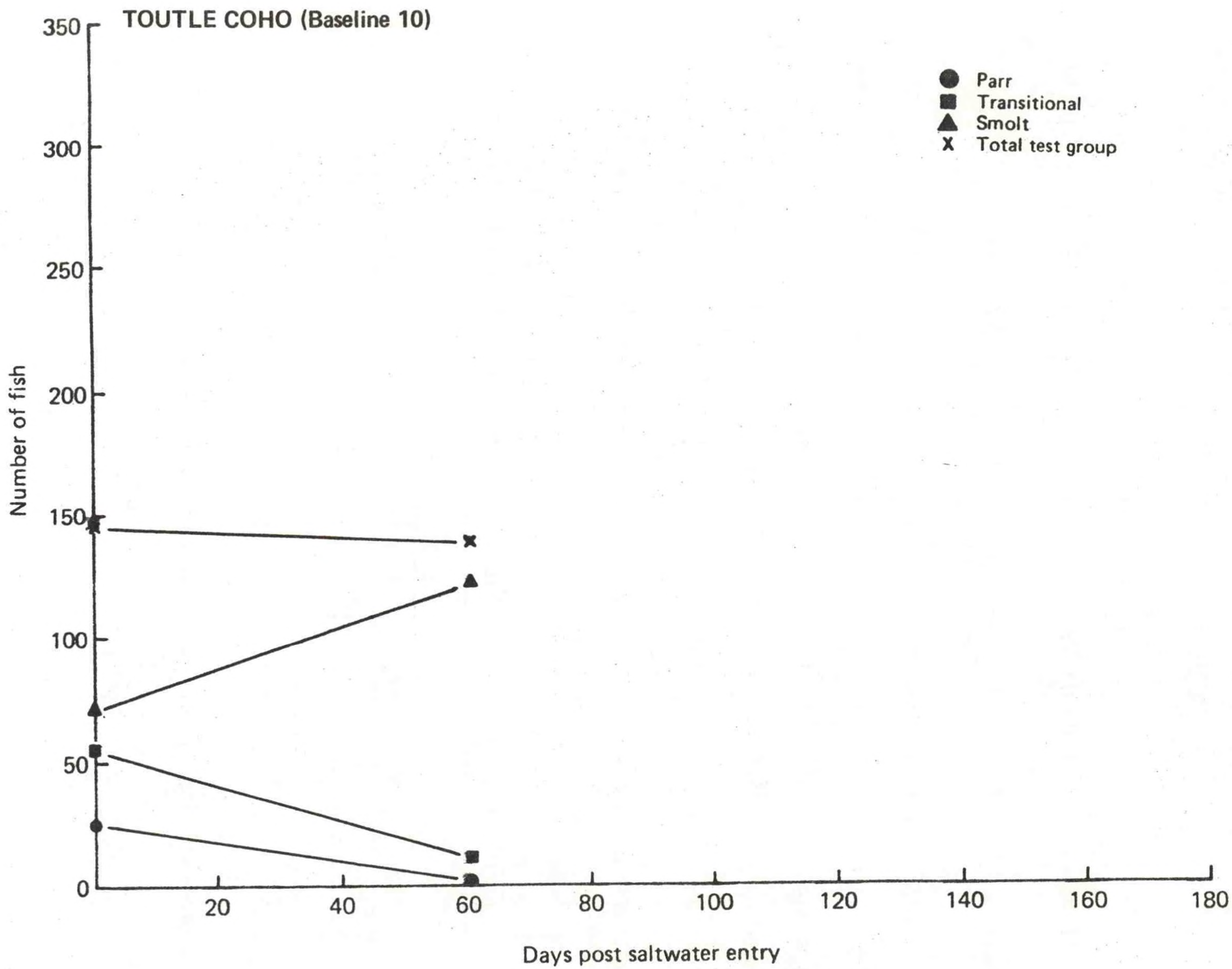


Figure 25.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Carson   Species: Spring Chinook   Stock: Carson

Date of Initial Observation: 05-02-79   Termination Date: 11-20-79   Elapsed Days: 202

Number of Replicates: 1   Total No. of Fish at Start: 200
Total No. of Fish at Termination: 41

Surface Water Temperature at Time of Saltwater entry: 9.0°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 9.20 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.0   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	10	0	5.0	0.0	15.2		110.4	
Transitional	109	0	54.5	0.0	21.4		124.8	
Smolt	78	41	39.0	100.0	25.8	131.9	133.3	216.4
Precocious	3	0	1.5	0.0	36.4		146.0	
Population	200	41	100.0	100.0	23.0	131.9	127.7	216.4

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 25   Figure(s): 26

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of seawater entry, this group was visually characterized as being composed of primarily transitional (55%) and smolted (39%) fish. By the third evaluation period (76 days), 78% were smolted, and at termination (202 days), all fish were characterized as smolts. Precocious males were present ranging from 2 to 15% of the population until the last observation period on 20 November at which time none were present.

Initial osmoregulatory dysfunction was minimal (6%). Mortality due to other causes occurred throughout the testing period with a peak occurring about 25 days after seawater entry. The mortality occurred primarily in the unvaccinated fish suggesting that vibrioses was the pathogen present. Fish having been dead for only 24 h were decomposed to a point that reliable bacterial cultures could not be obtained. Overall survival was relatively poor (20.5%) after 202 days of seawater residence.

TABLE 25.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Carson	Spring Chinook	05-02-79		length[a/]	110.4 ± 8.408[c/]	124.8 ± 6.270	133.3 ± 6.124	146.0 ± 11.789	127.7 ± 8.808
				weight[b/]	15.2 ± 4.835	21.4 ± 3.527	25.8 ± 4.190	36.4 ± 8.183	23.0 ± 5.053
				number	10	109	78	3	200
		06-06-79	35	length	118.0 ± 0.000	128.0 ± 5.923	136.6 ± 7.144	139.8 ± 7.189	135.8 ± 7.732
				weight	14.1 ± 0.000	22.7 ± 3.644	29.4 ± 4.904	32.3 ± 5.211	28.9 ± 5.495
				number	1	12	87	13	113
		07-17-79	41	length		134.2 ± 7.887	156.6 ± 7.986	144.2 ± 9.239	153.3 ± 10.544
				weight		26.4 ± 2.897	47.6 ± 9.055	38.1 ± 9.660	44.8 ± 10.655
				number	0	5	58	11	74
		08-27-79	41	length	131.0 ± 0.000		179.6 ± 12.571	143.0 ± 9.423	174.8 ± 17.654
				weight	22.6 ± 0.000		71.2 ± 15.144	34.0 ± 7.741	66.3 ± 19.371
				number	1	0	49	6	56
		11-20-79	85	length			216.4 ± 18.011		216.4 ± 18.011
				weight			131.9 ± 35.083		131.9 ± 35.083
				number	0	0	41	0	41

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

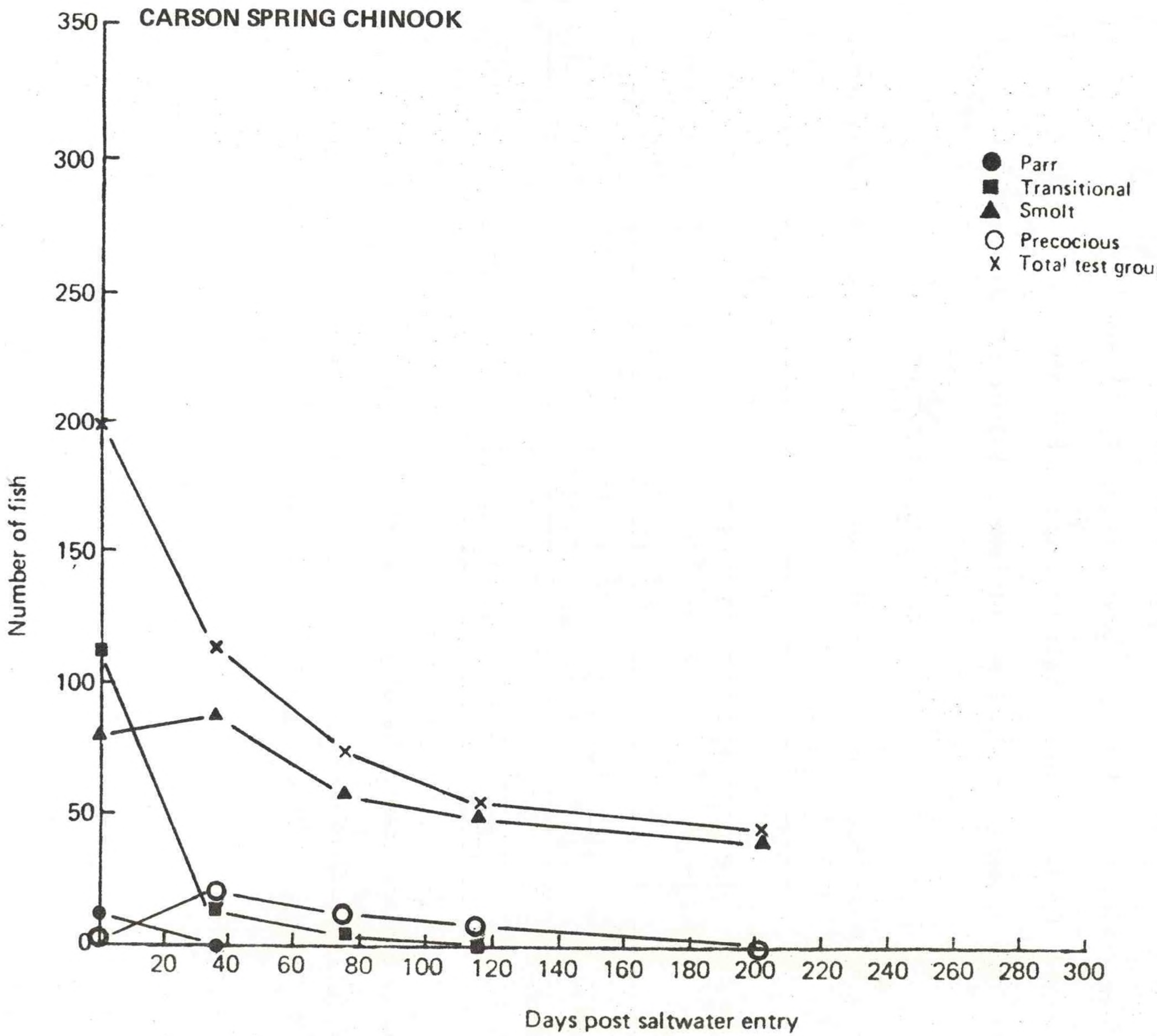


Figure 26.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Leavenworth Species: Spring Chinook Stock: Carson

Date of Initial Observation: 04-26-79 Termination Date: 11-20-79 Elapsed Days: 208

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 74

Surface Water Temperature at Time of Saltwater entry: 8.3°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.65 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.1 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	6	0	3.0	0.0	12.0		102.2	
Transitional	12	1	6.0	1.4	17.9	61.4	118.0	183.0
Smolt	182	73	91.0	98.6	26.3	182.0	133.5	241.0
Precocious	0	0	0.0	0.0				
Population	200	74	100.0	100.0	25.4	180.4	131.7	240.2

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 26 Figure(s): 27

OVERALL SEAWATER ADAPTATION

COMMENTS

At introduction to seawater, the majority of this test group were visually characterized as smolted fish. Initially no precocious males were present; however, by the second observation period (41 days), 6% of the population were so characterized. By 208 days of seawater residence, all precocious males died. *Vibrio* strains 775 and 1669 and BKD were isolated from moribund fish. Overall mortality (63%) was comparatively high for the test group.

TABLE 26.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Leavenworth	Spring Chinook	04-26-79		length[a]	102.2 ± 8.424[c]	118.0 ± 6.252	133.5 ± 10.536		131.7 ± 12.065
				weight[b]	12.0 ± 3.531	17.9 ± 3.559	26.3 ± 7.896		25.4 ± 8.206
				number	6	12	182	0	200
		06-06-79	41	length		124.0 ± 10.614	146.9 ± 10.582	163.3 ± 12.727	147.2 ± 11.743
				weight		21.1 ± 4.517	36.5 ± 9.197	53.9 ± 13.726	37.0 ± 10.356
				number	0	4	169	9	182
		07-17-79	41	length		132.3 ± 8.963	163.9 ± 12.872	162.3 ± 13.560	162.9 ± 13.771
				weight		25.5 ± 4.244	56.7 ± 15.946	56.3 ± 14.001	55.8 ± 16.410
				number	0	3	96	6	105
		08-27-79	41	length		151.0 ± 0.000	189.0 ± 15.179	166.3 ± 6.292	187.2 ± 16.218
				weight		37.5 ± 0.000	82.6 ± 21.049	63.3 ± 12.066	80.9 ± 21.572
				number	0	1	65	4	70
		11-20-79	85	length		183.0 ± 0.000	241.0 ± 21.403		240.2 ± 22.298
				weight		61.4 ± 0.000	182.0 ± 48.330		180.4 ± 50.005
				number	0	1	73	0	74

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

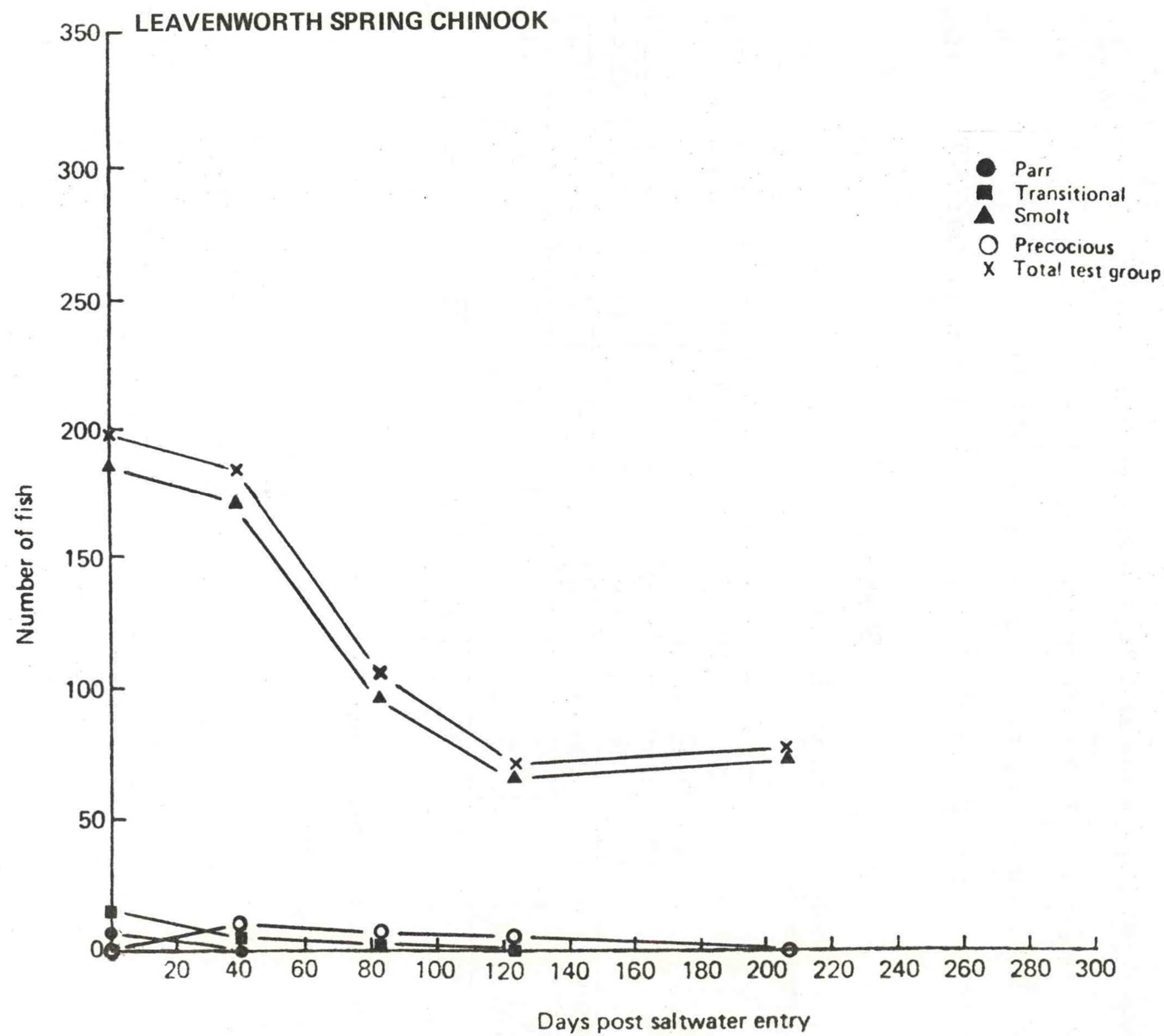


Figure 27.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Willard (Group 1) Species: Fall Chinook Stock: Little White Salmon

Date of Initial Observation: 07-11-79 Termination Date: 10-26-79 Elapsed Days: 107

Number of Replicates: 1

Total No. of Fish at Start: 300
Total No. of Fish at Termination: 62

Surface Water Temperature at Time of Saltwater entry: 11.7°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 7.53 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	163	16	54.3	25.8	3.3	10.5	68.0	94.9
Transitional	129	20	43.0	32.3	5.1	16.2	78.6	107.4
Smolt	8	26	2.7	41.9	6.3	28.8	83.4	127.3
Precocious	0	0	0.0	0.0				
Population	300	62	100.0	100.0	4.2	20.0	73.0	112.5

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 27 Figure(s): 28

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of seawater entry, this group of fish was primarily in a parr or transitional state of smoltification. Not until termination (107 days past seawater entry) did the number of smolts exceed the other stages.

Survival was poor initially from osmoregulatory problems but later from *Vibrio anguillarum*. Overall mortality was 79%. No precocious males were seen in this test group.

TABLE 27.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Willard Group 1	Fall Chinook	07-11-78		length[a/]	68.0 ± 7.629[c/]	78.6 ± 5.395	83.4 ± 6.345		73.0 ± 8.645
				weight[b/]	3.3 ± 1.166	5.1 ± 1.154	6.3 ± 1.461		4.2 ± 1.488
				number	163	129	8	0	300
		08-22-78	42	length	73.7 ± 5.521	86.1 ± 5.524	98.5 ± 4.737		83.9 ± 10.368
				weight	4.5 ± 1.295	8.1 ± 1.841	12.6 ± 2.102		7.6 ± 3.314
				number	66	84	33	0	183
		10-26-78	65	length	94.9 ± 7.898	107.4 ± 8.437	127.3 ± 8.093		112.5 ± 15.747
				weight	10.5 ± 2.385	16.2 ± 3.894	28.8 ± 5.946		20.0 ± 9.067
				number	16	20	26	0	62

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

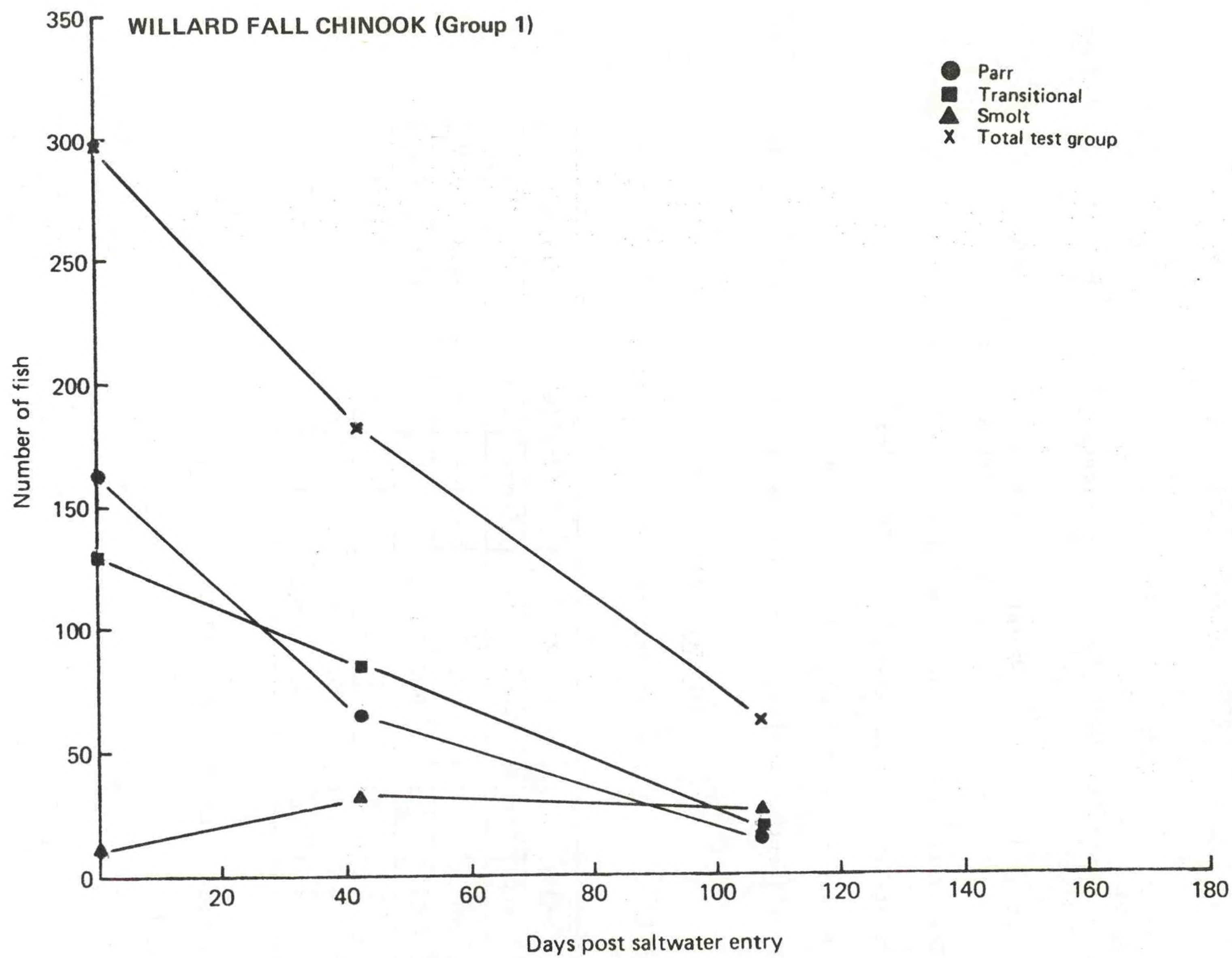


Figure 28.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Willard (Group 2)   Species: Fall Chinook   Stock: Little White Salmon

Date of Initial Observation: 10-31-79   Termination Date: 08-22-79   Elapsed Days: 295

Number of Replicates: 1   Total No. of Fish at Start: 300
Total No. of Fish at Termination: 49

Surface Water Temperature at Time of Saltwater entry: 12.0°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 6.30 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.9   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	209	2	67.9	4.1	10.8	25.0	99.3	129.5
Transitional	90	5	30.0	10.2	15.9	39.1	112.6	147.2
Smolt	1	41	0.3	83.7	21.0	60.4	125.0	168.2
Precocious	0	1	0.0	2.0		43.5		144.0
Population	300	49	100.0	100.0	12.4	56.4	103.7	164.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 28   Figure(s): 29

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, all but one of these fish were visually characterized as parr or transitional stage fish. Initial losses due to osmoregulatory stress were in excess of 28%. After 67 days, 18% of those fish remaining had assumed the appearance of smolts; however, by 150 days reversion had reduced this figure to less than 5%. Subsequently, the percent of smolts in the test group increased until by termination (295 days) 82% of those fish remaining had smolted.

The mortality rate was the greatest during the first 215 days of observation, due mainly to osmoregulatory difficulties and *Vibrio anguillarum*. Overall mortality was 84%.

At 258 days, 4 precocious males were observed in this test group.

TABLE 28.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Willard Group 2	Fall Chinook	10-31-78		length[a]	99.3 ± 11.102[c]	113.6 ± 6.117	125.0 ± 0.000		103.6 ± 11.885
				weight[b]	10.8 ± 3.491	15.9 ± 2.643	21.0 ± 0.000		12.4 ± 4.040
				number	209	90	1	0	300
		01-06-79	67	length	101.8 ± 5.780	113.5 ± 5.792	126.2 ± 5.179		113.3 ± 9.533
				weight	11.2 ± 1.957	16.5 ± 2.805	22.8 ± 3.242		16.5 ± 4.557
				number	42	118	36	0	196
		03-30-79	83	length	109.1 ± 7.881	122.1 ± 8.009	135.3 ± 9.437		117.3 ± 10.892
				weight	14.3 ± 3.535	21.3 ± 4.510	29.2 ± 7.109		18.7 ± 5.900
				number	56	72	6	0	134
		06-04-79	66	length	113.4 ± 8.647	130.1 ± 8.623	145.4 ± 7.697		129.6 ± 14.291
				weight	16.0 ± 4.660	25.2 ± 4.656	35.3 ± 5.434		25.3 ± 8.481
				number	24	43	23	0	90
		07-16-79	42	length	122.2 ± 5.541	133.4 ± 9.090	154.3 ± 10.725	137.8 ± 5.737	148.0 ± 14.668
				weight	18.4 ± 4.245	27.0 ± 6.558	43.0 ± 7.969	36.2 ± 0.954	38.5 ± 10.846
				number	5	7	43	4	59
		08-22-79	37	length	129.5 ± 3.536	147.2 ± 6.943	168.2 ± 11.010	144.0 ± 0.000	164.0 ± 14.410
				weight	25.0 ± 0.636	39.1 ± 6.631	60.2 ± 11.077	43.5 ± 0.000	56.4 ± 13.975
				number	2	5	41	1	49

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

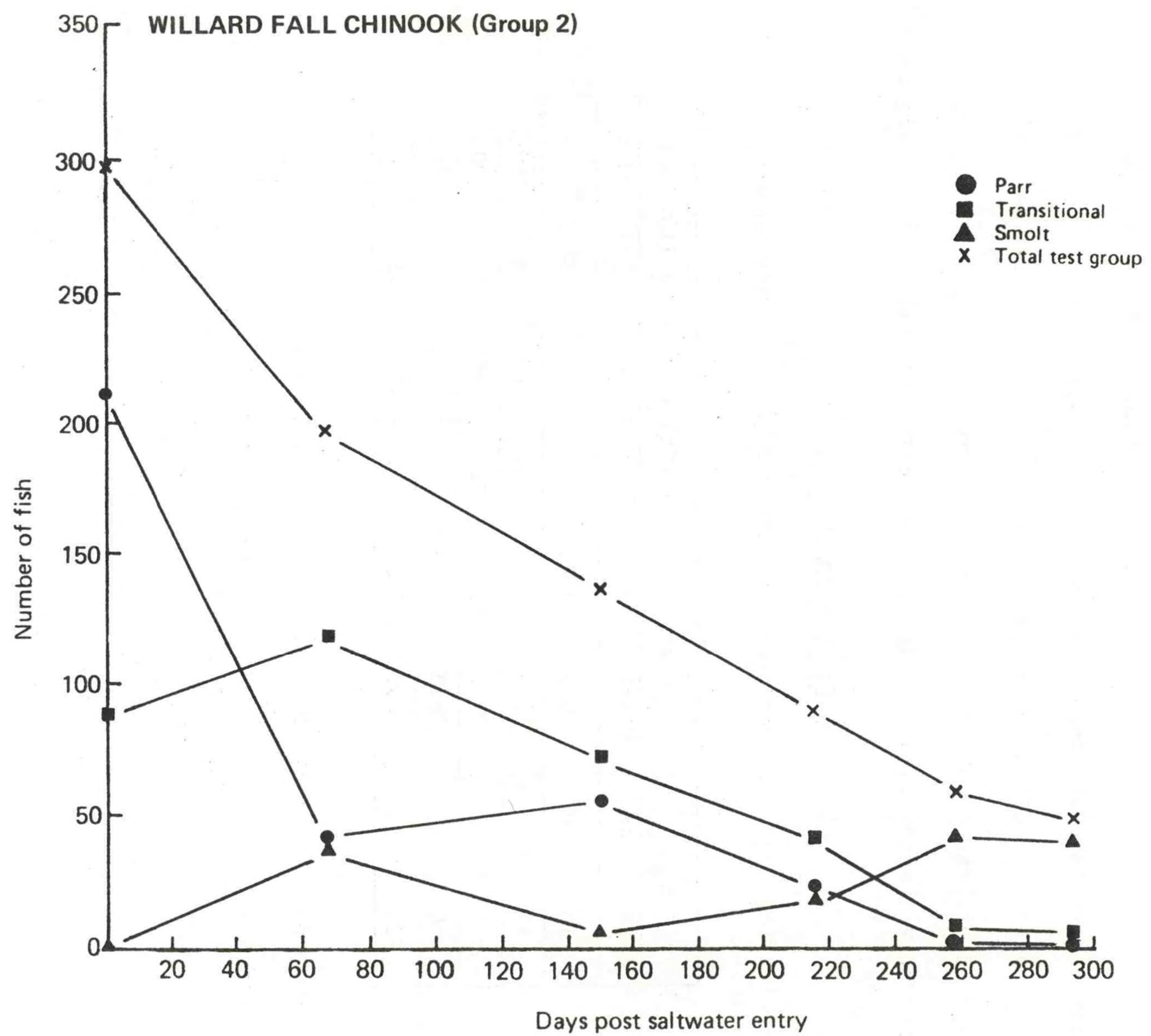


Figure 29.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Bonneville (1977 Brood) Species: Fall Chinook Stock: Bonneville

Date of Initial Observation: 03-19-79 Termination Date: 08-22-79 Elapsed Days: 156

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 219

Surface Water Temperature at Time of Saltwater entry: 7.6°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 27.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.99 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 6.3 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	16	0	5.3	0.0	20.6		122.2	
Transitional	45	2	15.0	0.9	30.0	29.1	138.4	143.5
Smolt	239	182	79.7	83.1	59.0	98.0	171.2	200.0
Precocious	0	35	0.0	16.0		117.0		210.9
Population	300	219	100.0	100.0	52.6	100.4	163.6	201.3

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 29 Figure(s): 30

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of entry to seawater, the majority of this test group had the visual appearance of smolts, with approximately 20% judged to be in a nonsmolted condition. Mortality attributed to osmoregulatory stress was less than 10% and occurred within 5 days of seawater entry. Pathogenic bacteria were isolated on only three occasions, 2 fish had BKD and 1 contained Vibrio Serotype 775.

Overall mortality for the 156-day observation period was less than 30%. Precocious males first appeared in the test group at 119 days after seawater entry, reaching a peak of 10%, of the remaining fish, by the 156th day. The high percentage of early maturing, noncontributing fish in this test group would be the only area for concern; otherwise, the test group appeared to have been well adapted for seawater survival.

TABLE 29.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Bonneville Late Yearling	Fall Chinook	03-19-79		length[a/]	122.2 ± 9.588[c/]	138.4 ± 10.551	171.2 ± 13.583		163.6 ± 20.016
				weight[b/]	20.6 ± 5.149	30.0 ± 7.322	59.0 ± 14.903		52.6 ± 18.701
				number	16	45	239	0	300
		06-04-79	77	length	119.0 ± 0.000	136.4 ± 11.343	180.6 ± 18.586		178.5 ± 20.669
				weight	17.6 ± 0.000	26.9 ± 6.904	68.0 ± 21.032		66.0 ± 22.387
				number	1	11	249	0	261
		07-16-79	42	length		123.0 ± 0.000	192.7 ± 19.590	200.9 ± 14.958	192.9 ± 19.923
				weight		19.0 ± 0.000	81.6 ± 24.530	97.3 ± 19.464	82.2 ± 24.805
				number	0	1	218	13	232
		08-22-79	37	length		143.5 ± 17.678	200.0 ± 18.437	210.9 ± 13.377	201.3 ± 18.934
				weight		21.0 ± 7.071	98.0 ± 25.744	117.0 ± 23.178	100.4 ± 27.023
				number	0	2	182	35	219

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

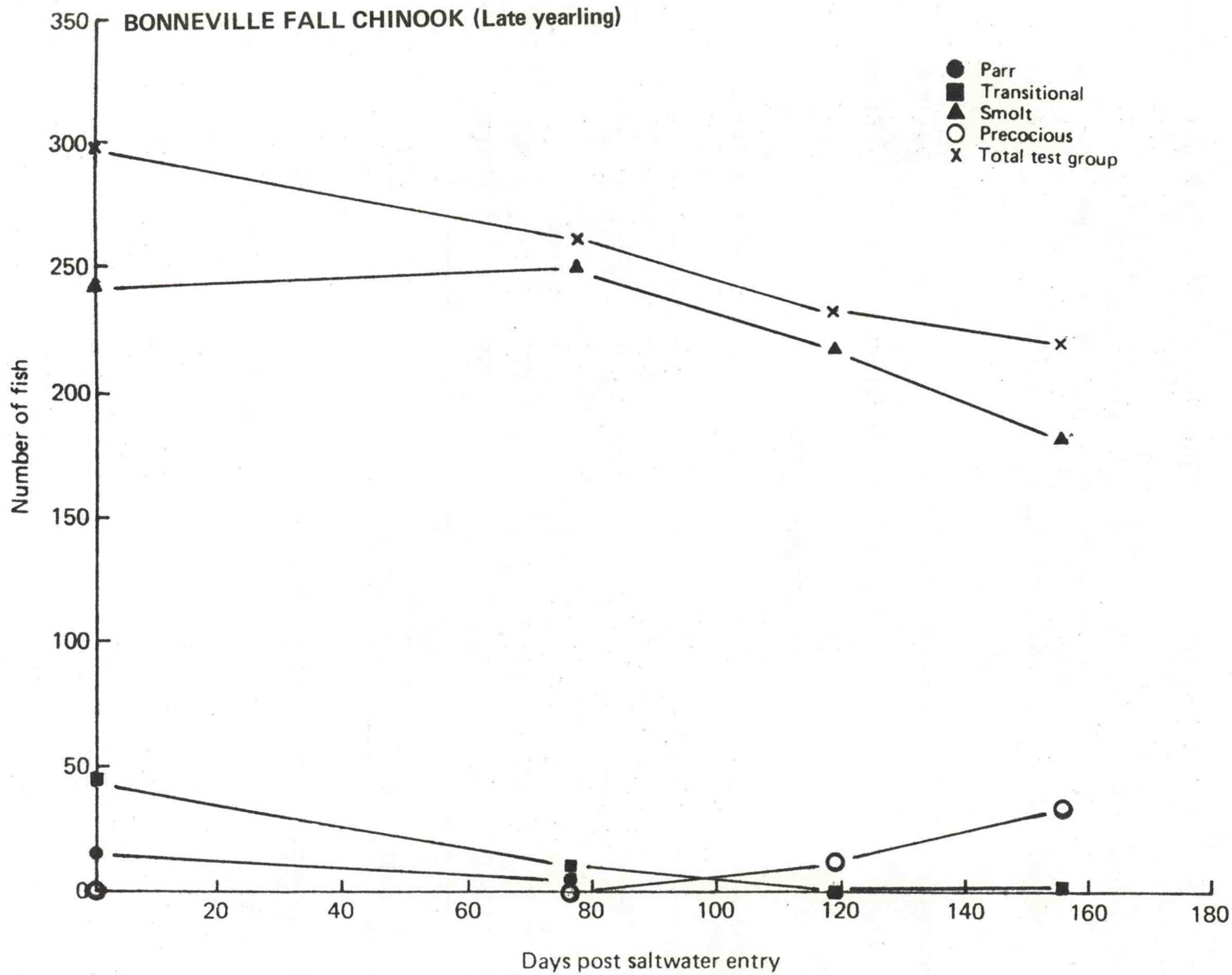


Figure 30.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Spring Creek (Group 1) Species: Fall Chinook Stock: Spring Creek

Date of Initial Observation: 3-21-79 Termination Date: 08-22-79 Elapsed Days: 154

Number of Replicates: 2 Total No. of Fish at Start: 303
Total No. of Fish at Termination: 67

Surface Water Temperature at Time of Saltwater entry: 7.7°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 27.5 ‰ Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.99 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 6.3 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	189	9	62.4	13.4	3.1	9.5	66.6	92.1
Transitional	114	24	37.6	35.8	4.2	17.3	73.3	109.7
Smolt	0	34	0.0	50.7		27.1		125.9
Precocious	0	0	0.0	0.0				
Population	303	67	100.0	100.0	3.5	21.2	69.1	115.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 30 Figure(s): 31

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of entry to seawater, fish in this test group were small, weighing 3.5 g. Most of the fish were considered to be in the parr stage whereas none were visually judged to be a smolt. After 117 days of seawater exposure, the test population consisted of 33% smolted fish, and the remaining fish were judged to be in the transitional and parr stages. By 154 days (end of test period), only 51% of the existing fish had the external characteristics of smolts. No precocious males were observed in this test group.

The test group suffered a high overall mortality (78% after 154 days). This mortality was attributed to the small size of the fish upon seawater entry and the high incidence of non-smolted fish.

During the first 10 days of seawater exposure, deaths attributed to osmoregulatory stress were greater than 30%. However, fish had clinical symptoms of vibriosis (6 fish with Serotype 775 and 3 fish with Serotype 1669).

TABLE 30.--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Spring Creek Group 1	Fall Chinook	03-21-79		length[a] weight[b] number	66.6 ± 4.378[c] 3.1 ± 0.670 189	73.3 ± 3.255 4.2 ± 0.705 114	0	0	69.1 ± 5.168 3.5 ± 0.877 303
		06-04-79	75	length weight number	80.1 ± 7.096 5.5 ± 1.671 120	89.6 ± 4.619 7.8 ± 1.336 25	0	0	81.7 ± 7.624 5.9 ± 1.831 145
		07-16-79	42	length weight number	82.2 ± 7.164 5.7 ± 2.15[illegible] 22	96.3 ± 6.400 9.9 ± 2.187 39	111.1 ± 12.779 14.7 ± 3.664 30	0	97.8 ± 14.170 10.5 ± 4.346 91
		08-22-79	37	length weight number	92.1 ± 3.723 9.5 ± 1.893 9	109.7 ± 7.647 17.1 ± 3.940 24	125.9 ± 11.126 27.1 ± 8.147 34	0	115.6 ± 15.053 21.2 ± 9.035 67

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

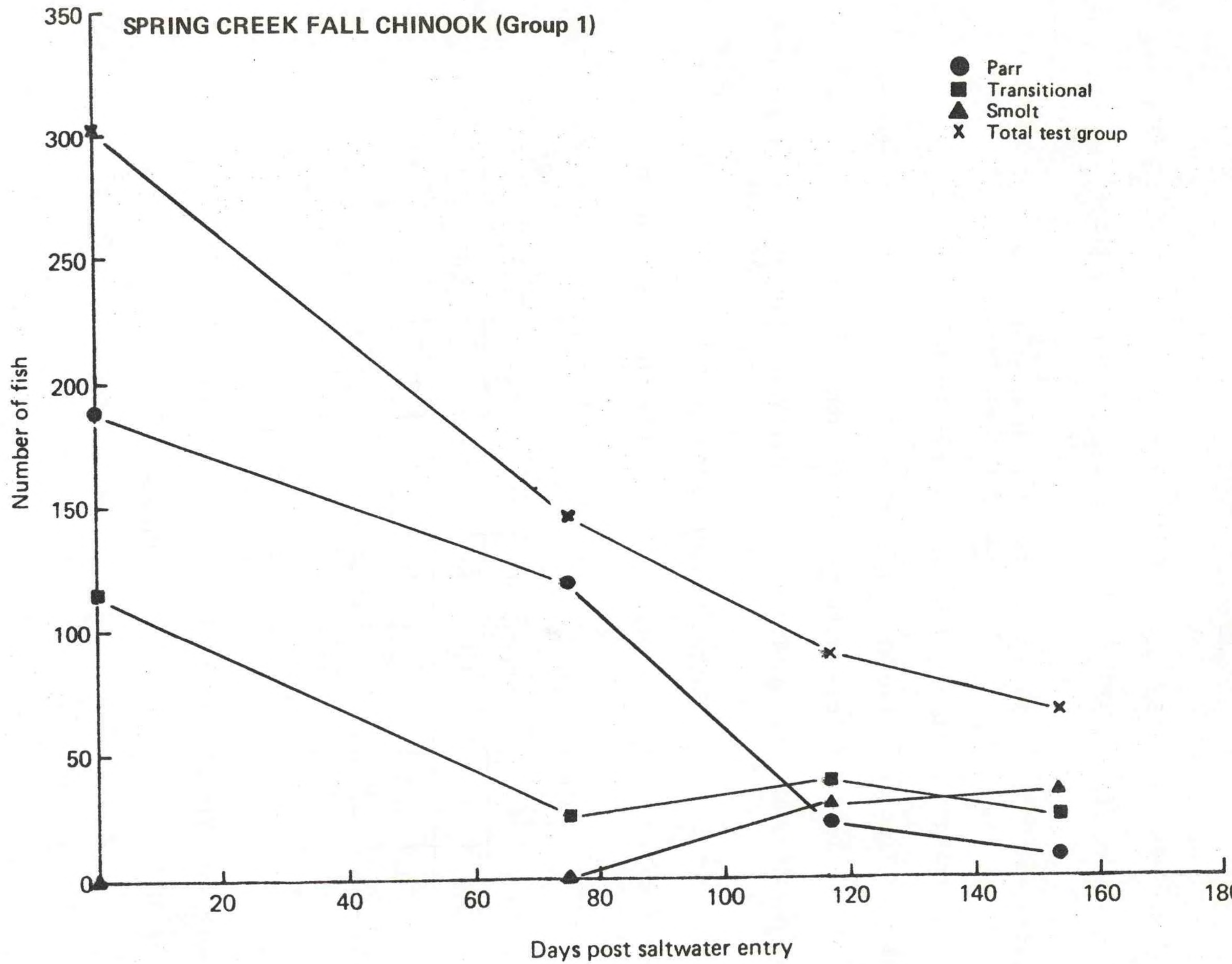


Figure 31.--Number of parred, transitional,and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Spring Creek (Group 2) Species: Fall Chinook Stock: Spring Creek

Date of Initial Observation: 04-20-79 Termination Date: 11-26-79 Elapsed Days: 220

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 12

Surface Water Temperature at Time of Saltwater entry: No Reading Figure: 3

Surface Salinity at Time of Saltwater Entry: No Reading Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No Reading Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	279	0	93.0	0.0	4.6	0	76.3	0
Transitional	21	3	7.0	25.0	6.5	29.7	84.5	136.3
Smolt	0	9	0.0	75.0		39.6		150.7
Precocious	0	0	0.0	0.0				
Population	300	12	100.0	100.0	4.7	37.2	76.8	147.1

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 31 Figure(s): 32

OVERALL SEAWATER ADAPTATION

COMMENTS

None of the fish in this test group had the external appearance of smolts at the time of entry to seawater. Even after 45 days, less than 1% of these fish had smolted. The percentage of smolted fish did not exceed 50% until after 124 days. No losses due to osmoregulatory dysfunction were observed in this test group.

Vibrio anguillarum, Strains 775 and 1669, were first isolated approximately 20 days after saltwater entry, but did not become a severe problem until after 124 days, when the mortality rate increased dramatically. At termination (220 days) only 4% of the original number of fish had survived.

No precocious males were observed in this test group.

TABLE 31.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Spring Creek Group 2	Fall Chinook	04-20-79		length[a]	76.3 ± 6.241[c]	84.5 ± 4.422			76.8 ± 6.479
				weight[b]	4.6 ± 1.199	6.5 ± 1.040	0	0	4.7 ± 1.638
				number	279	21			300
		06-04-79	45	length	80.2 ± 6.113	89.4 ± 4.556	99.0 ± 4.242		82.8 ± 7.185
				weight	5.7 ± 1.434	8.1 ± 1.330	11.2 ± 0.565	0	6.4 ± 1.828
				number	166	60	2		228
		07-16-79	42	length	84.7 ± 6.376	100.4 ± 6.023	110.6 ± 6.533		99.7 ± 11.783
				weight	6.4 ± 1.581	11.2 ± 2.152	15.2 ± 2.649	0	11.2 ± 4.030
				number	51	78	65		194
		08-22-79	37	length	94.5 ± 9.220	113.3 ± 7.667	127.3 ± 8.053		118.7 ± 13.258
				weight	9.7 ± 3.608	18.2 ± 3.818	26.5 ± 5.417	0	21.7 ± 7.346
				number	12	42	60		114
		11-26-79	96	length	0	136.3 ± 5.859	150.7 ± 9.708		147.1 ± 10.808
				weight	0	29.7 ± 7.247	39.6 ± 7.568	0	37.2 ± 8.441
				number	0	3	9		12

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

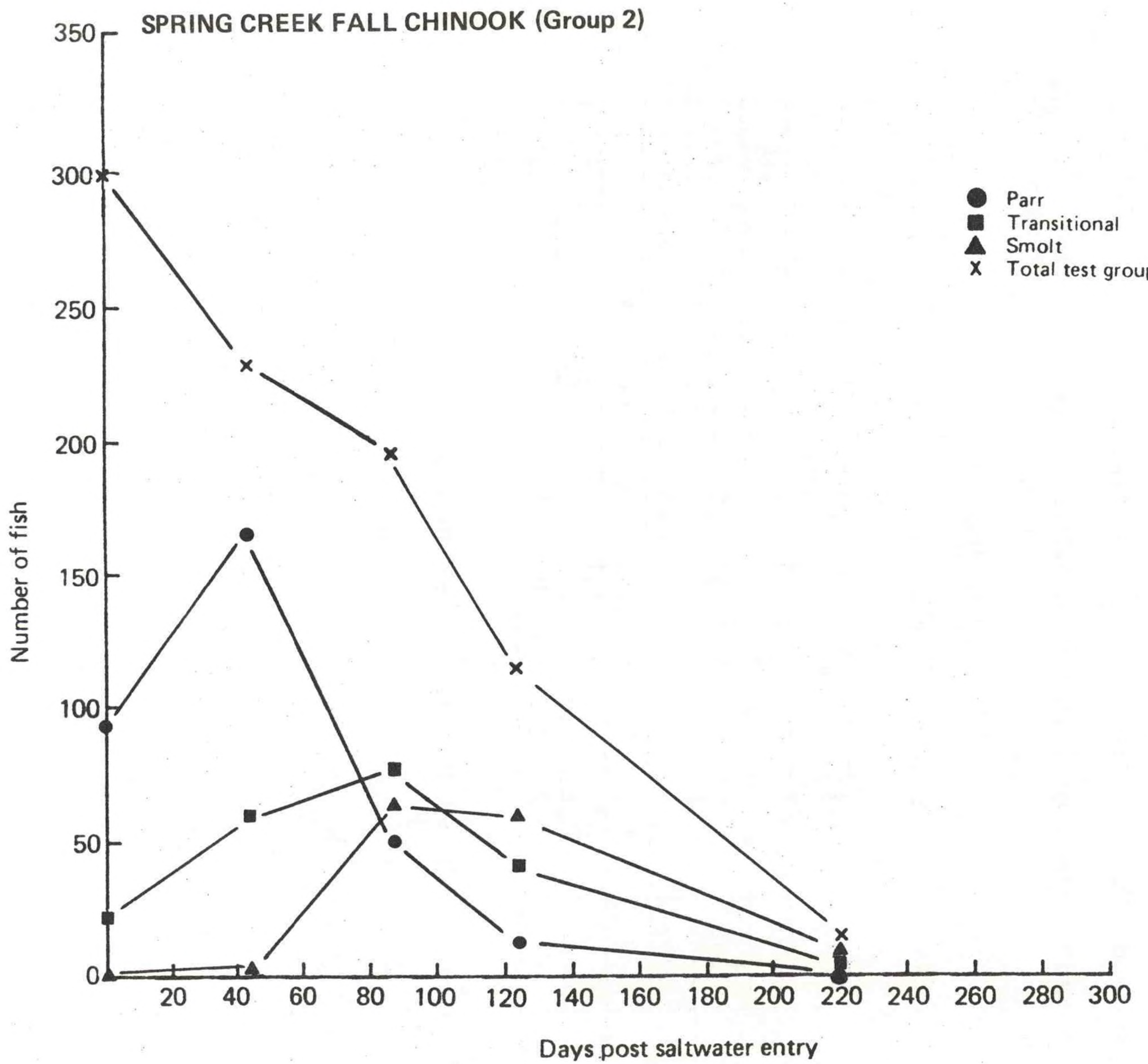


Figure 32.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Willard (Group 3) Species: Fall Chinook Stock: Little White Salmon

Date of Initial Observation: 04-20-79 Termination Date: 08-22-79 Elapsed Days: 124

Number of Replicates: 2

Total No. of Fish at Start: 300

Total No. of Fish at Termination: 43

Surface Water Temperature at Time of Saltwater entry: No Reading Figure: 3

Surface Salinity at Time of Saltwater Entry: No Reading Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No Reading Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No Reading Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	98	7	32.7	16.3	11.9	24.0	103.8	130.6
Transitional	164	11	54.7	25.6	18.5	35.5	119.9	141.9
Smolt	38	24	12.7	55.8	25.7	51.8	132.8	160.1
Precocious	0	1	0.0	2.3		43.2		152.0
Population	300	43	100.0	100.0	17.2	42.9	116.3	150.5

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 32 Figure(s): 33

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of introduction to seawater, less than 13% of these fish were visually characterized as smolted fish. This figure did not exceed 50% until after 87 days. Initial mortality due to osmoregulatory stress was less than 11%.

Total mortality, due mostly to undetermined cause(s), was more than 60% for the first 45 days and by 124 days (termination) had reached more than 85%.

At 87 days, 2 precocious males were observed in the test group.

TABLE 32.--Test group growth and survival at different stages of development during the seawater adaptation study.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Willard Group 3	Fall Chinook	04-20-79		length[a/]	103.8 ± 10.333[c/]	119.9 ± 8.396	132.8 ± 7.589		116.3 ± 13.159
				weight[b/]	11.9 ± 3.620	18.5 ± 4.105	25.7 ± 4.438		17.2 ± 5.930
				number	98	164	38	0	300
		06-04-79	45	length	110.1 ± 12.157	122.8 ± 7.873	136.5 ± 6.230		121.3 ± 12.116
				weight	14.8 ± 4.921	19.9 ± 3.967	28.0 ± 4.396		19.7 ± 5.833
				number	23	52	12	0	87
		07-16-79	42	length	112.0 ± 12.166	128.3 ± 4.606	145.8 ± 8.955	135.0 ± 4.243	137.4 ± 12.703
				weight	12.8 ± 3.239	21.9 ± 2.810	33.9 ± 6.783	28.9 ± 0.000	28.3 ± 8.566
				number	3	21	32	2	58
		08-22-79	37	length	130.6 ± 7.569	141.9 ± 5.594	160.1 ± 10.588	152.0 ± 0.000	150.5 ± 14.681
				weight	24.0 ± 3.923	35.5 ± 3.583	51.8 ± 11.721	43.2 ± 0.000	42.9 ± 14.115
				number	7	11	24	1	43

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

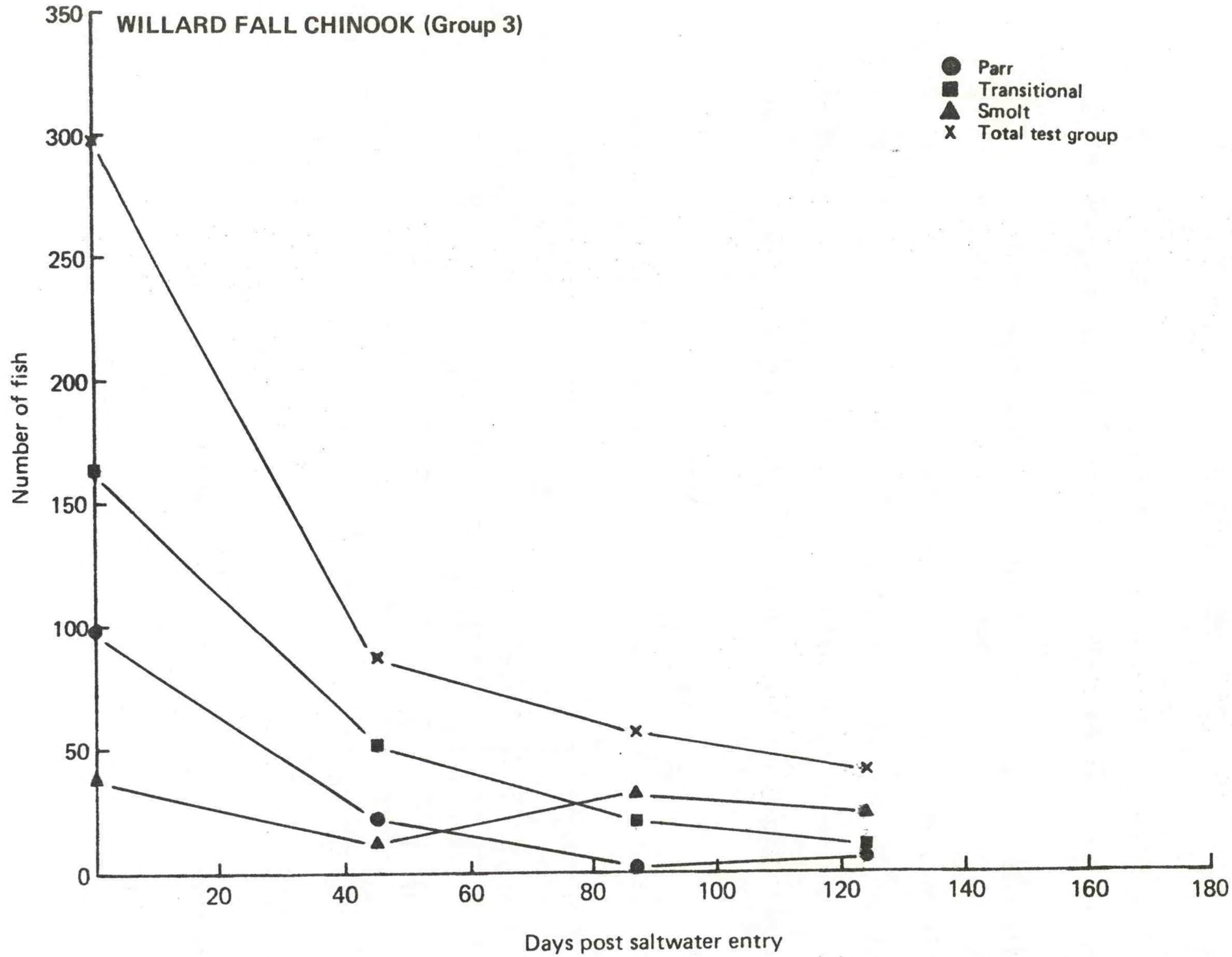


Figure 33.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Big White Salmon   Species: Fall chinook   Stock: Spring Creek

Date of Initial Observation: 05-21-79   Termination Date: 11-26-79   Elapsed Days: 189

Number of Replicates: 1   Total No. of Fish at Start: 150
Total No. of Fish at Termination: 11

Surface Water Temperature at Time of Saltwater entry: 10.5°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 10.38 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.1   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	20	0	13.3	0	6.3	0	84.7	0
Transitional	107	6	71.3	54.5	7.5	27.6	89.2	136.2
Smolt	23	5	15.3	45.5	9.7	43.8	97.5	155.4
Precocious	0	0	0.0	0.0				
Population	150	11	100.0	100.0	7.7	35.0	89.9	144.9

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 33   Figure(s): 34

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater only 15% of the test group were visually characterized as smolts with the majority of the remaining fish in the transitional stage. The number of smolted fish never exceeded 45% of the population for any given observation period.

Immediate mortality from osmoregulatory stress was slight; however, transitional stage fish showed overt signs of stress throughout the study. Mortality was moderate until approximately 70 days of saltwater residence, after which the overall mortality increased dramatically. The overall mortality of this test group was 93%. *Vibrio anguillarum* was first isolated from dead fish 25 days after seawater entry and was believed to be responsible for the majority of mortalities in this test group.

No precocious males were observed in this test group.

TABLE 33.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Big White Salmon	Fall Chinook	05-21-79		length[a/] weight[b/] number	84.7 ± 5.974[c/] 6.3 ± 1.701 20	89.2 ± 5.844 7.5 ± 1.647 107	97.5 ± 3.629 9.7 ± 1.325 23	0	89.9 ± 6.614 7.6 ± 1.868 150
		07-17-79	57	length weight number	91.1 ± 2.720 9.0 ± 1.088 18	101.4 ± 6.188 12.6 ± 2.397 58	110.2 ± 6.001 16.4 ± 2.954 57	0	103.8 ± 8.665 13.7 ± 3.615 133
		08-23-79	37	length weight number	101.5 ± 7.984 12.3 ± 3.182 10	113.9 ± 6.767 17.5 ± 3.340 39	127.6 ± 6.900 25.9 ± 4.545 36	0	118.3 ± 11.272 20.4 ± 6.273 85
		11-26-79	95	length weight number	0	136.2 ± 11.161 27.6 ± 6.264 6	155.4 ± 13.353 43.8 ± 12.324 5	0	144.9 ± 15.313 35.0 ± 12.306 11

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

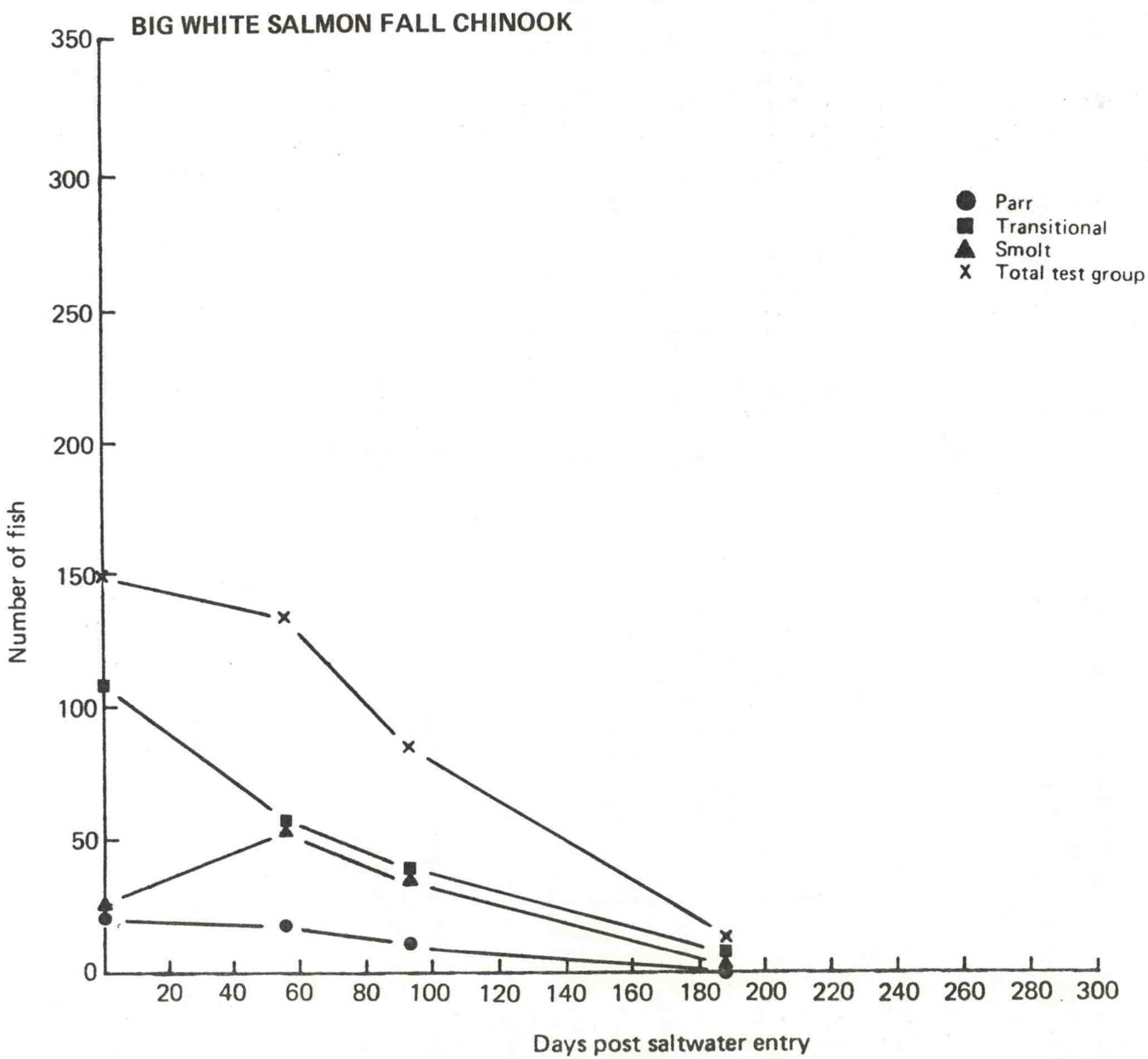


Figure 34.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Spring Creek (Group 3)   Species: Fall chinook   Stock: Spring Creek

Date of Initial Observation: 05-21-79   Termination Date: 11-26-79   Elapsed Days: 189

Number of Replicates: 2   Total No. of Fish at Start: 300
Total No. of Fish at Termination: 7

Surface Water Temperature at Time of Saltwater entry: 10.5°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 10.38 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.1   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	116	0	38.7	0.0	6.4		85.3	
Transitional	156	1	52.0	14.3	8.6	36.0	93.7	149.0
Smolt	28	6	9.3	85.7	10.6	45.8	100.1	156.7
Precocious	0	0	0.0	0.0				
Population	300	7	100.0	100.0	8.0	44.4	91.0	155.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 34   Figure(s): 35

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, over 90% of this test group had the external appearance of parr or transitional stage fish. Subsequently, the percentage of smolted fish showed a general increase to approximately 40% after 94 days of seawater residence.

Initial mortality from osmoregulatory dysfunction was 13%. *Vibrio anguillarum* was first isolated 4 days after seawater entry, but was not prevalent until after 56 days, when the mortality rate dramatically increased so that by termination (189 days) overall mortality was 99%.

No precocious males were observed in this test group.

TABLE 34.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Spring Creek Group 3	Fall Chinook	05-21-79		length[a/]	85.3 ± 6.619[c/]	93.7 ± 5.095	100.1 ± 4.814		91.0 ± 7.525
				weight[b/]	6.4 ± 1.591	8.6 ± 1.594	10.6 ± 1.717		8.0 ± 2.103
				number	116	156	28	0	300
		06-19-79	29	length	83.2 ± 6.252	94.5 ± 6.559	98.7 ± 7.226		94.3 ± 7.673
				weight	5.6 ± 1.530	8.9 ± 2.133	10.1 ± 2.669		8.8 ± 2.469
				number	18	145	39	0	202
		07-16-79	27	length	89.8 ± 6.628	103.7 ± 5.932	111.4 ± 6.496		104.9 ± 9.570
				weight	7.2 ± 1.981	12.0 ± 2.186	15.1 ± 2.923		12.6 ± 3.665
				number	30	87	84	0	201
		08-23-79	38	length	105.1 ± 6.848	117.9 ± 7.101	130.0 ± 6.640		121.1 ± 10.675
				weight	12.4 ± 2.567	18.5 ± 3.577	25.9 ± 4.718		20.7 ± 6.095
				number	14	57	46	0	117
		11-26-79	95	length	0	149.0 ± 0.000	156.7 ± 18.651		155.6 ± 17.271
				weight	0	36.0 ± 0.000	45.8 ± 17.762		44.4 ± 16.636
				number	0	1	6	0	7

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

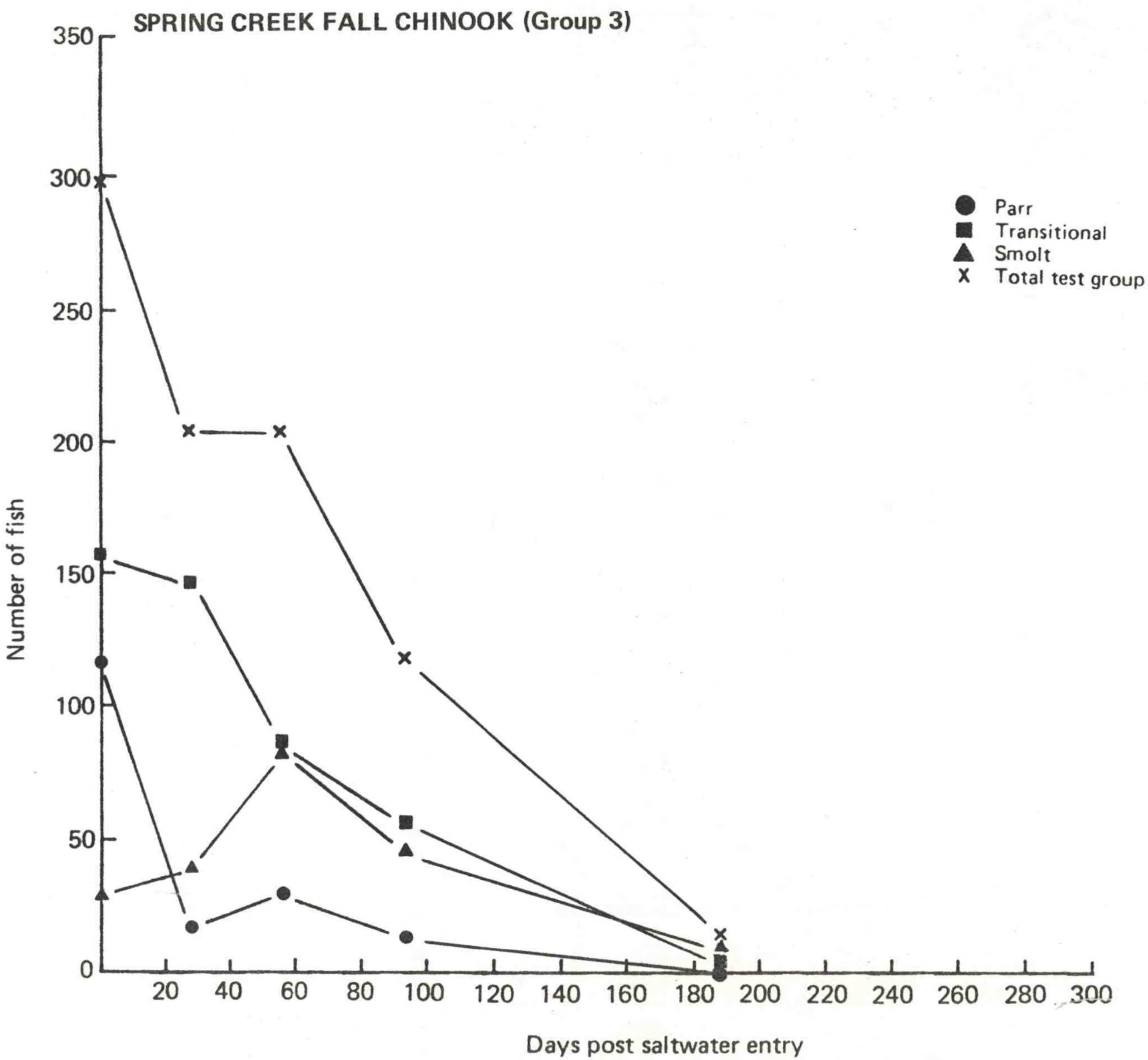


Figure 35.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Bonneville (1978 Brood Stock-Tule) Species: Fall chinook Stock: Bonneville

Date of Initial Observation: 05-30-79 Termination Date: 11-26-79 Elapsed Days: 180

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 12

Surface Water Temperature at Time of Saltwater entry: 11.2°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.82 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	100	2	33.3	16.7	4.5	21.1	74.5	125.5
Transitional	187	3	62.3	25.0	7.2	33.9	87.0	144.3
Smolt	13	7	4.3	58.3	9.6	51.0	94.8	162.1
Precocious	0	0	0.0	0.0				
Population	300	12	100.0	100.0	6.4	41.8	83.2	151.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 35 Figure(s): 36

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, only 4% of this Bonneville test group had the visual appearance of smolts. After 47 days, 22% of the remaining fish appeared to be smolted, and a peak 54% of the remaining population appeared to be smolted after 85 days in seawater. Initial loss due to osmoregulatory stress was 18%.

After 47 days, only 39% of the fish survived. Infection with *Vibrio anguillarum* affected the test group throughout the experimental period (180 days) overall mortality in this group was 90%.

No precocious males were observed in this test group.

TABLE 35.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Bonneville Tules - 78 Brood	Fall Chinook	05-30-79		length[a/]	74.5 ± 7.593[c/]	87.0 ± 5.005	94.8 ± 3.693		83.2 ± 8.695
				weight[b/]	4.5 ± 1.421	7.2 ± 1.285	9.6 ± 1.336		6.4 ± 1.955
				number	100	187	13	0	300
		07-16-79	47	length	88.2 ± 9.491	100.7 ± 6.221	108.8 ± 6.216		99.8 ± 9.814
				weight	7.6 ± 2.163	11.3 ± 2.425	14.6 ± 2.373		11.2 ± 3.290
				number	25	66	26	0	117
		08-23-79	38	length	92.3 ± 3.055	110.6 ± 7.785	123.9 ± 8.390		117.0 ± 11.555
				weight	9.0 ± 0.681	16.2 ± 4.176	23.8 ± 5.911		20.0 ± 6.731
				number	3	28	36	0	67
		11-26-79	95	length	125.5 ± 3.536	144.3 ± 8.963	162.1 ± 11.539		151.6 ± 17.244
				weight	21.1 ± 0.990	33.9 ± 9.592	51.0 ± 12.385		41.8 ± 15.804
				number	2	3	7	0	12

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

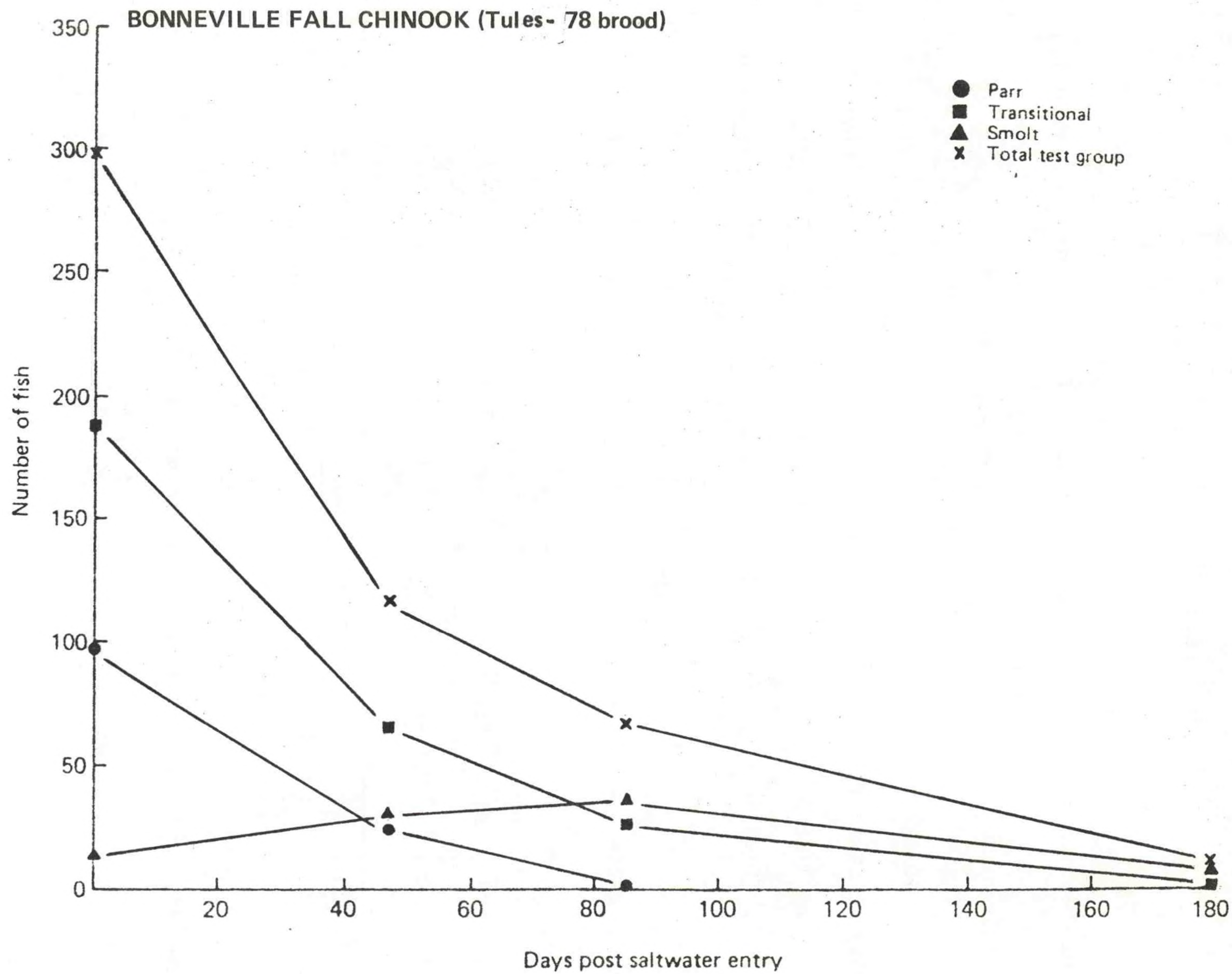


Figure 36.--Number of parred, transitional,and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Washougal Species: Fall Chinook Stock: Washougal/Toutle

Date of Initial Observation: 06-14-79 Termination Date: 11-26-79 Elapsed Days: 165

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 48

Surface Water Temperature at Time of Saltwater entry: 11.6°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 ‰ Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.69 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\bar{X}$ (Wt) (g)		$\bar{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	203	2	67.7	4.2	3.9	15.6	72.2	114.0
Transitional	82	9	27.3	18.8	5.6	23.2	81.1	127.4
Smolt	15	37	5.0	77.1	6.4	43.9	85.0	153.5
Precocious	0	0	0.0	0.0				
Population	300	48	100.0	100.0	4.5	38.9	75.3	147.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 36 Figure(s): 37

OVERALL SEAWATER ADAPTATION

COMMENTS

When transferred to seawater, 5% of the Washougal Fall Chinook salmon test group had the external appearance of smolts, 27% of transitional and 68% of parred fish. Approximately 15% of the test fish died from osmoregulatory dysfunction within 15 days of entry to seawater. The percentage of smolted fish increased steadily to a peak value of 77% of survivors at 165 days (termination).

Vibrio anguillarum was the only bacterial pathogen isolated from dead fish and is believed to be responsible for the majority of deaths subsequent to the osmoregulatory difficulty. Overall mortality was 84% for this test group.

No precocious males were observed.

TABLE 36.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Washougal	Fall Chinook	06-14-79		length[a/]	72.2 ± 6.176[c/]	81.1 ± 5.183	85.0 ± 3.722		75.2 ± 7.371
				weight[b/]	3.8 ± 1.035	5.6 ± 1.122	6.4 ± 0.894		4.4 ± 1.372
				number	203	82	15	0	300
		07-18-79	34	length	71.6 ± 5.279	83.4 ± 4.502	93.0 ± 4.924		83.7 ± 9.698
				weight	3.9 ± 1.041	6.3 ± 1.103	8.7 ± 1.452		6.5 ± 2.258
				number	58	82	79	0	219
		08-23-79	36	length	81.3 ± 5.816	95.7 ± 5.490	108.8 ± 7.120		98.4 ± 11.907
				weight	6.0 ± 1.405	10.7 ± 2.206	16.4 ± 3.531		12.2 ± 4.808
				number	26	55	57	0	138
		11-26-79	95	length	114.0 ± 0.000	127.4 ± 13.436	153.5 ± 13.991		147.0 ± 18.273
				weight	15.6 ± 0.000	23.2 ± 6.901	43.9 ± 13.294		38.9 ± 15.284
				number	2	9	37	0	48

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

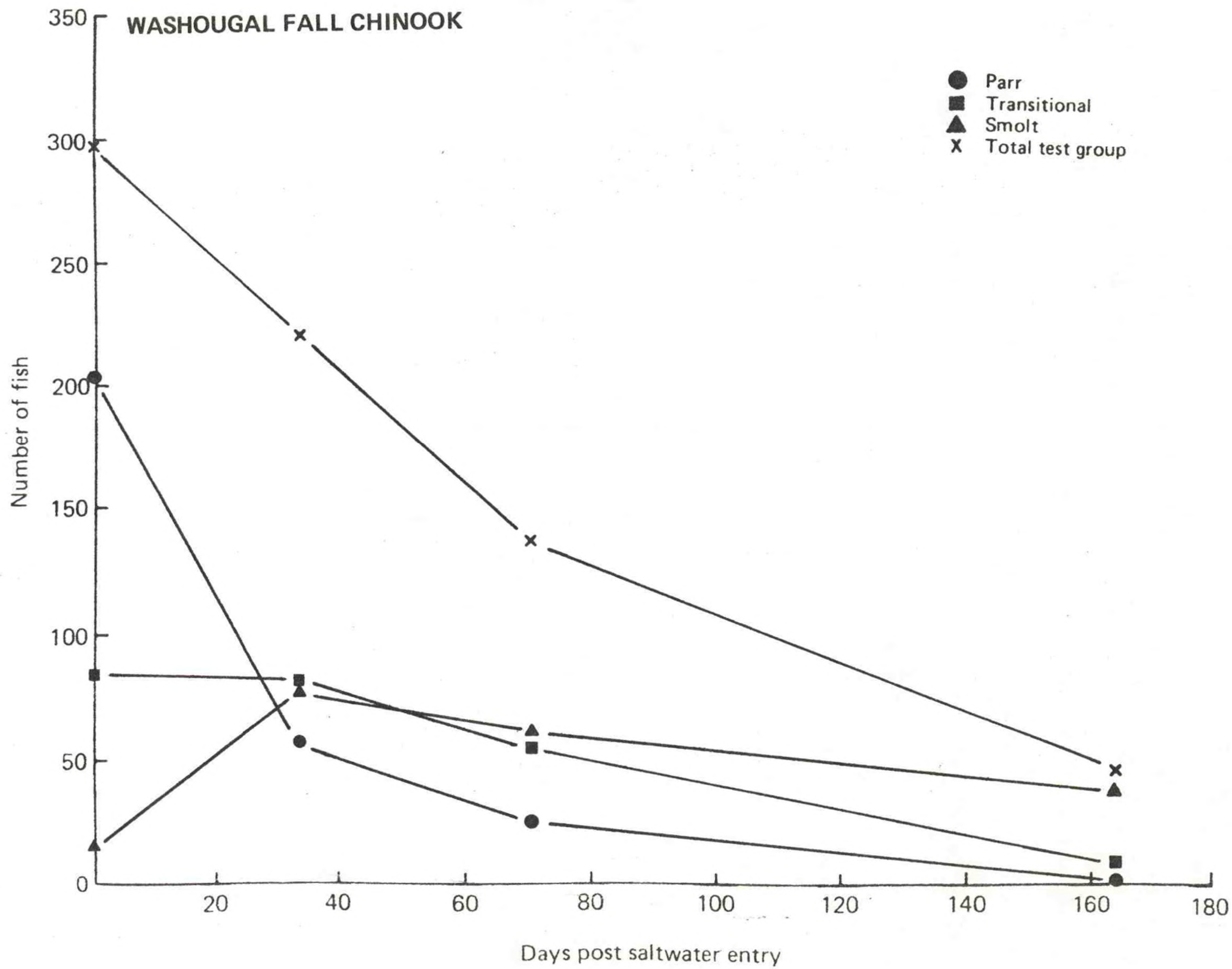


Figure 37.--Number of parred, transitional,and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Elokomin Species: Fall chinook Stock: Elokomin

Date of Initial Observation: 06-14-79 Termination Date: 11-26-79 Elapsed Days: 165

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 36

Surface Water Temperature at Time of Saltwater entry: 11.6°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 29.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.69 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	152	4	50.7	11.1	3.7	15.7	68.9	116.0
Transitional	133	7	44.3	19.4	5.1	22.4	76.8	127.6
Smolt	15	25	5.0	69.4	6.2	39.1	80.9	148.8
Precocious	0	0	0.0	0.0				
Population	300	36	100.0	100.0	4.4	33.2	73.0	141.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 37 Figure(s): 38

OVERALL SEAWATER ADAPTATION

COMMENTS

When introduced to seawater, only 5% of this test group exhibited the external characteristics of smolted fish. The percentage of smolted fish increased to 69% by the time of termination (165 days). No mortalities associated with short-term osmoregulatory stress were observed.

After 34 days, survival was an excellent 93% and at 70 days still exceeded 64%. Subsequently, however, mortality caused by *Vibrio anguillarum* was severe and continuous, so that by termination total mortality was 88%.

No precocious males were observed in this test group.

TABLE 37.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Elokomin	Fall Chinook	06-14-79		length[a/]	68.9 ± 5.365[c/]	76.8 ± 4.186	80.9 ± 3.844		73.0 ± 6.418
				weight[b/]	3.7 ± 0.851	5.1 ± 0.944	6.2 ± 1.234		4.4 ± 1.206
				number	152	133	15	0	300
		07-18-79	34	length	73.6 ± 7.293	84.9 ± 5.360	92.0 ± 4.644		85.2 ± 8.313
				weight	4.4 ± 1.306	6.5 ± 1.377	8.3 ± 1.399		6.7 ± 1.928
				number	48	139	91	0	278
		08-23-79	36	length	83.4 ± 6.066	95.8 ± 5.754	105.9 ± 6.965		99.3 ± 9.877
				weight	6.5 ± 1.612	10.4 ± 2.092	14.4 ± 3.310		11.9 ± 3.853
				number	23	73	95	0	191
		11-26-79	95	length	116.0 ± 8.327	127.6 ± 7.068	148.8 ± 12.036		141.0 ± 16.259
				weight	15.7 ± 3.814	22.4 ± 3.102	39.1 ± 11.315		33.2 ± 13.178
				number	4	7	25	0	36

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

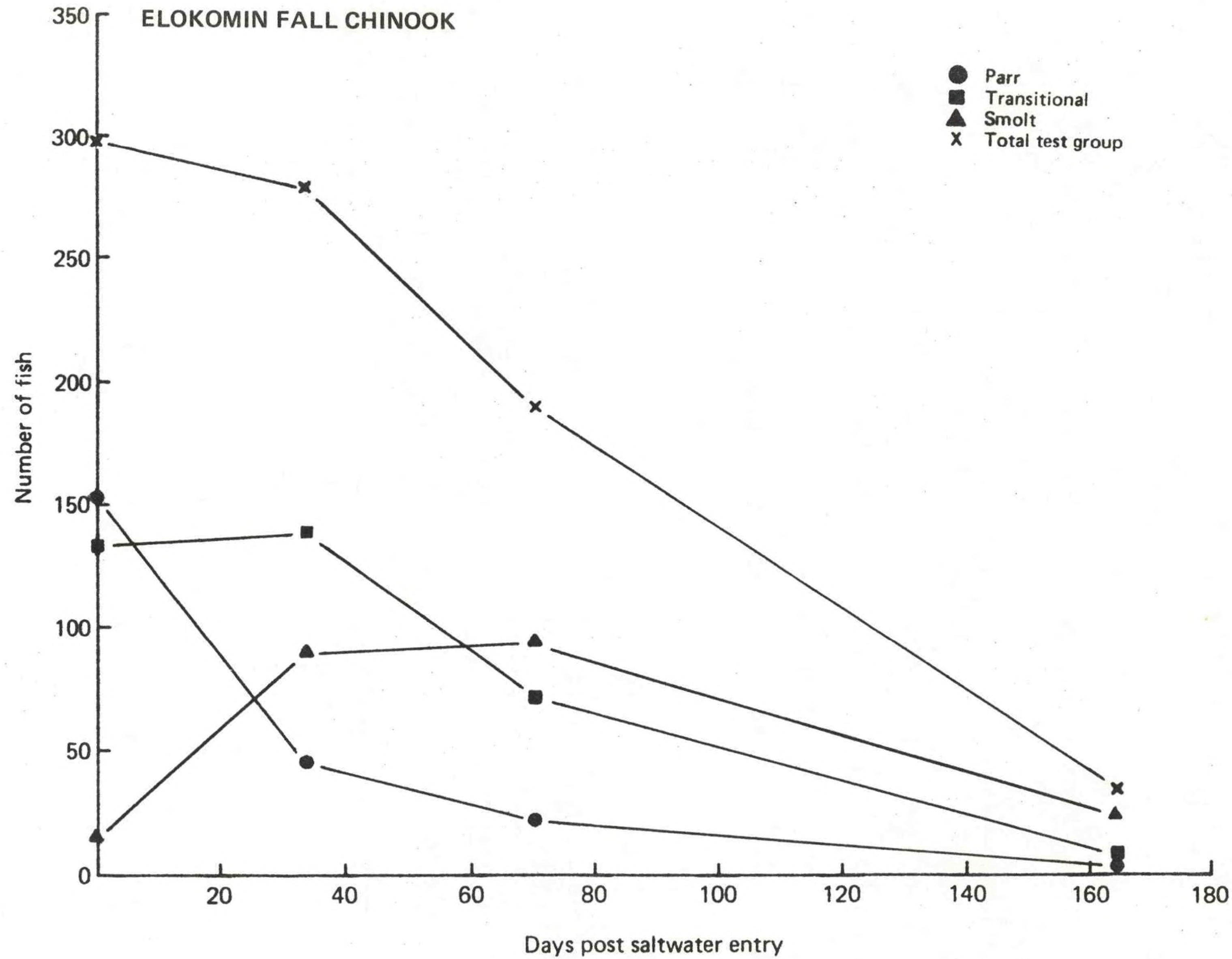


Figure 38.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Little White Salmon Species: Fall chinook Stock: Little White Salmon

Date of Salwtaer Entry: 06-27-79 Termination Date: 11-26-79 Elapsed Days in Salt Water: 153

Number of Replicates: 2 Total No. of Fish at Start: 301
Total No. of Fish at Termination: 37

Surface Water Temperature at Time of Saltwater entry: 12.0 Figure: 3

Surface Salinity at Time of Saltwater Entry: 30.0 Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 3.34 Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Engry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smolification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	114	7	37.9	18.9	3.3	13.8	68.3	111.3
Transitional	176	12	58.5	32.4	4.7	23.2	76.5	129.2
Smolt	11	18	3.7	48.6	6.9	36.8	85.6	147.3
Precocious	0	0	0	0	0	0	0	0
Population	301	37	100.0	100.0	4.2	28.1	73.7	134.6

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 38 Figure(s): 39

OVERALL SEAWATER ADAPTATION

COMMENTS

When transferred to seawater, less than 4% of this test group was visually characterized as smolts, with this figure increasing to 49% after 153 days (termination). Twenty-one percent of the test group died due to osmoregulatory dysfunction within the first 15 days of seawater residence.

After 60 days of seawater residence, the mortality increased so that by the time of termination the overall mortality of this test group was 88%. The majority of these deaths were attributed to infection with *Vibrio anguillarum*.

No precocious males were observed in this test group.

TABLE 38.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Little White Salmon	Fall Chinook	06-26-79		length[a/]	68.3 ± 4.420[c/]	76.5 ± 5.014	85.6 ± 4.738		73.7 ± 6.619
				weight[b/]	3.3 ± 0.665	4.7 ± 0.998	6.9 ± 1.368		4.2 ± 1.236
				number	114	176	11	0	301
		08-24-79	59	length	82.4 ± 5.805	95.6 ± 5.379	107.2 ± 6.908		97.1 ± 11.298
				weight	6.5 ± 1.614	10.8 ± 2.017	15.8 ± 3.379		11.7 ± 4.417
				number	37	61	63	0	161
		11-26-79	94	length	111.3 ± 10.547	129.2 ± 7.424	147.3 ± 10.221		134.6 ± 16.763
				weight	13.8 ± 3.069	23.2 ± 3.897	36.8 ± 9.264		28.1 ± 11.523
				number	7	12	18	0	37

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

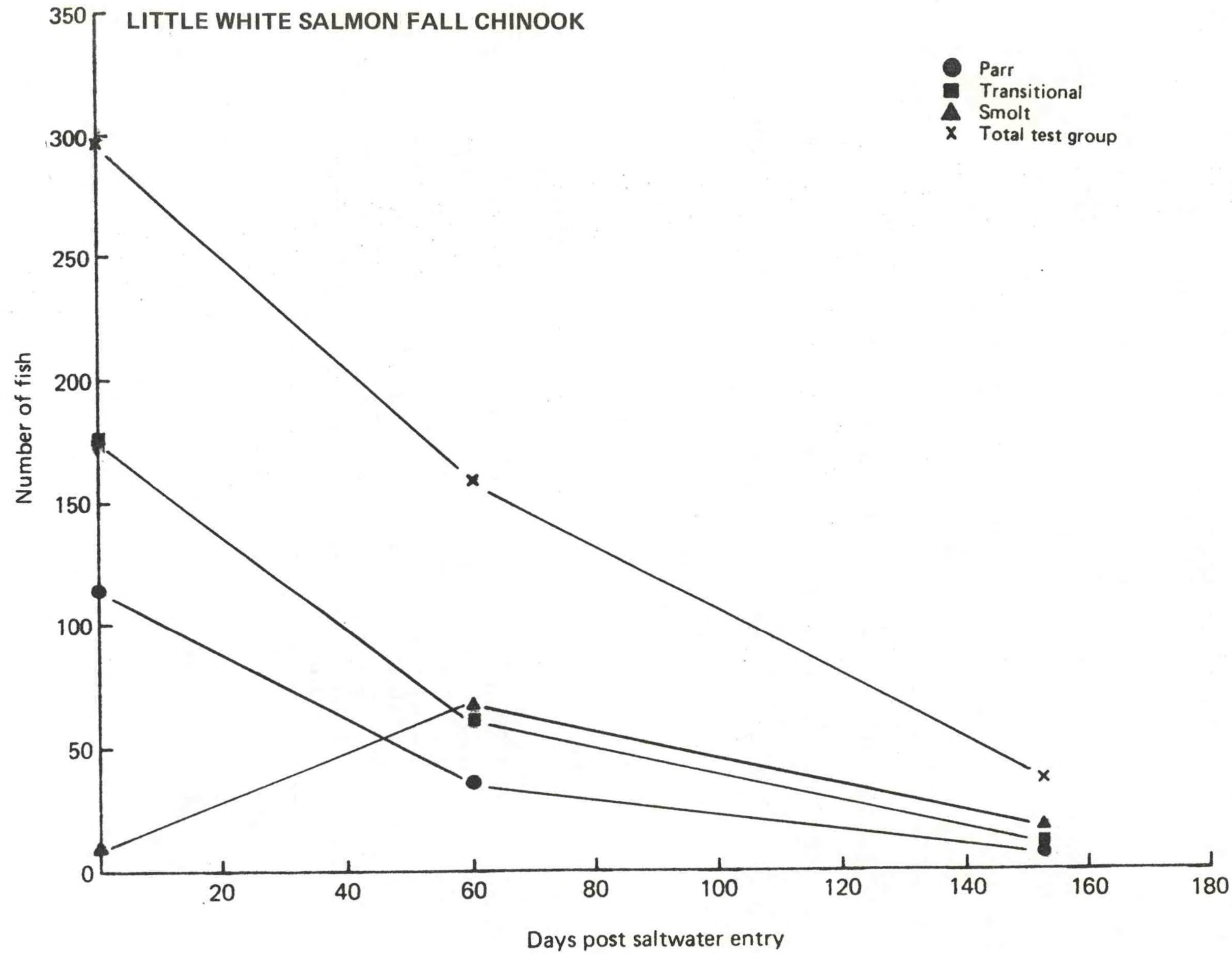


Figure 39.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Toutle Species: Fall chinook Stock: Green River

Date of Initial Observation: 06-26-79 Termination Date: 11-26-79 Elapsed Days: 153

Number of Replicates: 1 Total No. of Fish at Start: 133
Total No. of Fish at Termination: 41

Surface Water Temperature at Time of Saltwater entry: 12.0°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 30.0 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.34 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 4.0 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	75	11	56.4	26.8	3.1	9.1	66.3	93.0
Transitional	54	7	40.6	17.1	4.3	19.8	74.0	122.6
Smolt	4	23	3.0	56.1	4.8	33.9	77.2	142.9
Precocious	0	0	0.0					
Population	133	41	100.0	100.0	3.6	24.8	69.8	126.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 39 Figure(s): 40

OVERALL SEAWATER ADAPTATION

COMMENTS

The majority of the fish in this test group were very small and visually characterized as parr stage fish at seawater entry. Few immediate losses from osmoregulatory dysfunction were observed. However, smolted fish never comprised more than 29% of the population, thus indicating possible long term osmoregulatory difficulty in the marine environment. This difficulty, we believe, often manifests itself in reduced resistance to disease. *Vibrio anguillarum* was the only bacterial pathogen isolated from dead fish and is considered to be directly responsible for the majority of the mortality. Total mortality after 153 days was 87% in this test group.

No precocious males were observed.

TABLE 39.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Toutle	Fall Chinook	06-26-79		length[a]	66.3 ± 5.543[c]	74.0 ± 3.389	77.2 ± 1.500		69.8 ± 6.147
				weight[b]	3.1 ± 0.775	4.3 ± 0.770	4.8 ± 0.346		3.6 ± 0.991
				number	75	54	4	0	133
		08-23-79	58	length	78.2 ± 7.861	91.9 ± 5.113	101.3 ± 4.677		88.8 ± 10.443
				weight	5.4 ± 1.670	9.1 ± 1.763	12.3 ± 2.172		8.3 ± 3.042
				number	24	33	12	0	69
		11-26-79	95	length	95.8 ± 11.819	126.0 ± 6.506	145.0 ± 13.509		122.7 ± 21.971
				weight	10.1 ± 4.029	21.5 ± 3.147	35.0 ± 10.775		22.1 ± 11.581
				number	5	7	5	0	17

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

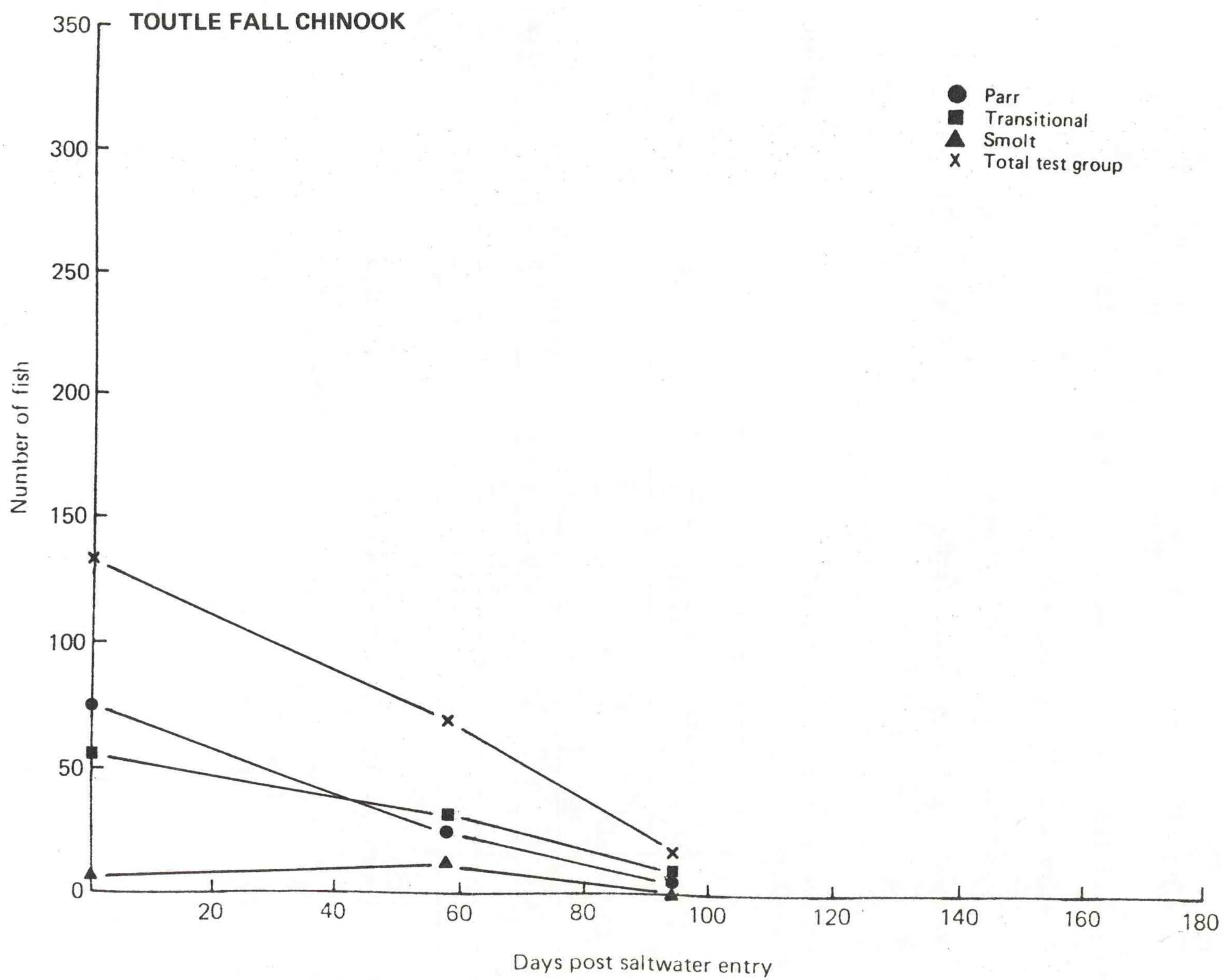


Figure 40.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Kalama Falls | Species: Fall chinook | Stock: Kalama Falls

Date of Initial Observation: 07-17-79 | Termination Date: 11-26-79 | Elapsed Days: 132

Number of Replicates: 2 | Total No. of Fish at Start: 300
Total No. of Fish at Termination: 41

Surface Water Temperature at Time of Saltwater entry: 13.0°C | Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 ‰ | Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 7.61 ppm | Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 3.5 | Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	106	11	35.3	26.8	3.5	9.1	70.0	93.0
Transitional	194	7	64.7	17.1	4.9	19.8	78.8	122.6
Smolt	0	23	0.0	56.1		33.9		142.9
Precocious	0	0	0.0	0.0				
Population	300	41	100.0	100.0	4.4	24.8	75.7	126.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 40 | Figure(s): 41

OVERALL SEAWATER ADAPTATION

COMMENTS

None of the fish in this test group was visually characterized as a smolt when transferred to seawater. Over 40% of the fish died from osmoregulatory dysfunction after exposure to seawater. By termination (132 days), 56% of the remaining fish appeared to be smolts.

Infection by *Vibrio anguillarum* was observed after 15 days and continued until termination. Final mortality was 86%.

No precocious males were observed in this test group.

TABLE 40.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Kalama Falls	Fall Chinook	07-17-79		length[a]	70.0 ± 7.064[c]	78.8 ± 8.659			75.7 ± 9.145
				weight[b]	3.5 ± 1.126	4.9 ± 1.589			4.4 ± 1.594
				number	106	194	0	0	300
		08-24-79	38	length	76.5 ± 6.465	91.8 ± 4.859	104.5 ± 5.774		88.5 ± 12.392
				weight	5.1 ± 1.418	9.0 ± 1.619	13.5 ± 2.522		8.4 ± 3.689
				number	45	41	25	0	111
		11-26-79	94	length	93.0 ± 9.539	122.6 ± 8.791	142.9 ± 13.424		126.0 ± 24.467
				weight	9.1 ± 2.853	19.8 ± 4.061	33.9 ± 12.321		24.8 ± 14.415
				number	11	7	23	0	41

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

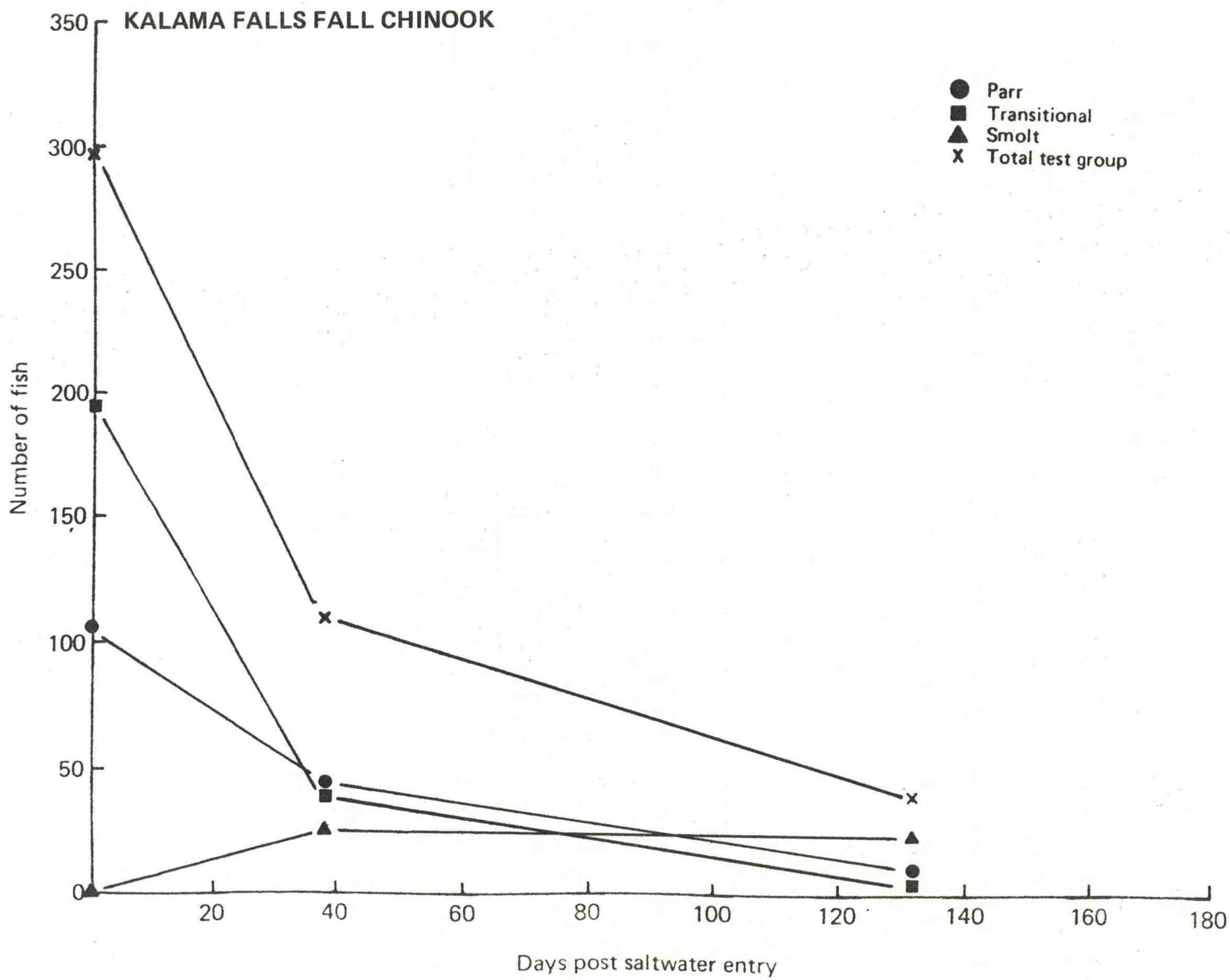


Figure 41.--Number of parred, transitional,and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Spring Creek (Group 4) Species: Fall chinook Stock: Spring Creek

Date of Initial Observation: 08-13-79 Termination Date: 11-26-79 Elapsed Days: 105

Number of Replicates: 2 Total No. of Fish at Start: 300
Total No. of Fish at Termination: 232

Surface Water Temperature at Time of Saltwater entry: 13.1°C Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 7.91 ppm Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 3.5 Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	12	8	4.0	3.4	9.7	20.2	97.5	126.0
Transitional	58	25	19.3	10.8	15.0	33.0	122.5	143.9
Smolt	226	199	75.3	85.8	21.2	60.1	125.7	170.7
Precocious	4	0	1.3	0.0	19.3		120.0	
Population	300	232	100.0	100.0	19.5	55.8	122.0	166.3

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 41 Figure(s): 42

OVERALL SEAWATER ADAPTATION

COMMENTS

Over 75% of these fish had the external appearance of smolts when introduced to seawater. No osmoregulatory difficulty was observed. After 105 days (termination), 85% of the fish were smolted.

Vibrio anguillarum was observed throughout the test period, but not in major proportions. Final mortality was 23%.

Four precocious males (1.3%) were recorded at day zero, but had died by the termination of the test.

TABLE 41.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Spring Creek Group 4	Fall Chinook	08-13-79		length[a/] weight[b/] number	97.5 ± 10.229[c/] 9.7 ± 2.853 12	112.5 ± 6.967 15.0 ± 2.869 58	125.7 ± 7.318 21.2 ± 3.905 226	120.0 ± 7.118 19.3 ± 2.567 4	122.0 ± 10.298 19.5 ± 4.827 300
		11-26-79	105	length weight number	126.0 ± 9.681 20.2 ± 3.900 8	143.9 ± 7.756 33.0 ± 6.028 25	170.7 ± 14.429 60.1 ± 16.299 199	0	166.3 ± 17.737 55.8 ± 18.641 232

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

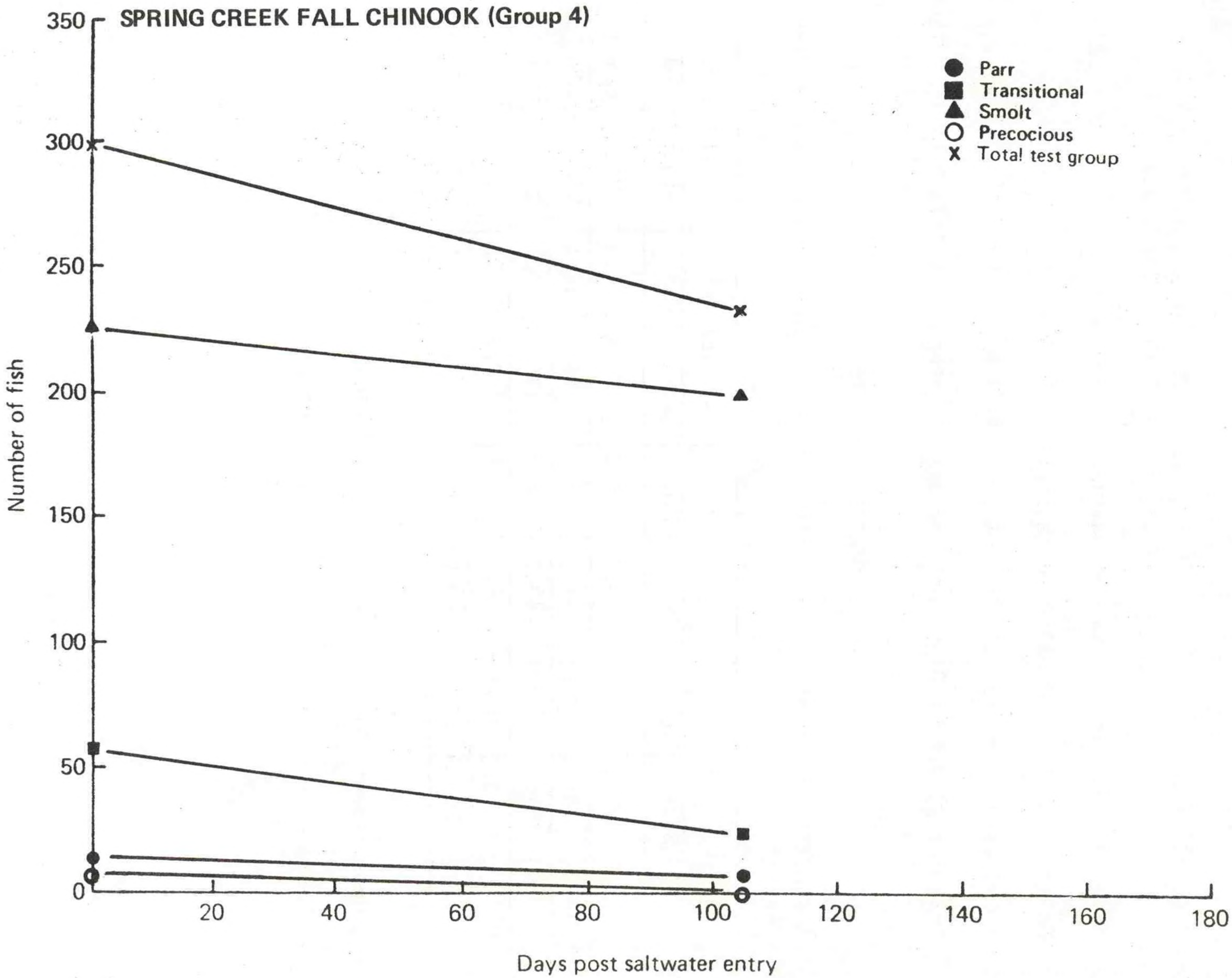


Figure 42.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Chelan (Leavenworth)　　Species: Steelhead　　Stock: Chelan

Date of Initial Observation: 04-26-79　　Termination Date: 11-20-79　　Elapsed Days: 208

Number of Replicates: 1　　Total No. of Fish at Start: 200
Total No. of Fish at Termination: 16

Surface Water Temperature at Time of Saltwater entry: 8.3°C　　Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.5 °/oo　　Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 8.65 ppm　　Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 5.1　　Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	8	1	4.0	6.3	78.6	97.0	204.2	225.0
Transitional	84	3	42.0	18.8	104.7	112.1	220.7	230.7
Smolt	95	9	47.5	56.3	124.9	215.1	235.0	275.2
Precocious	13	3	6.5	18.8	107.8	232.8	215.8	270.7
Population	200	16	100.0	100.0	113.5	191.8	226.5	262.9

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 42　　Figure(s): 43

OVERALL SEAWATER ADAPTATION

COMMENTS

At the time of introduction to seawater, the test group contained mostly transitional and smolted fish with 7% classified as precocious males. These precocious fish had all died by 82 days of seawater residence. Losses due to osmoregulatory dysfunction were about 28% in spite of 48% of the fish being smolted at seawater entry. Reversion from an apparent smolt or transitional stage to a transitional or parr stage, did take place after 82 days in seawater. This suggests that those fish which were judged to be smolts based upon external characteristics were not physiologically true smolts.

Vibrio Strain 775 was the bacterial pathogen most commonly isolated from moribund fish.

TABLE 42.--Length and weight of fish during different stages of development in salt water.

Test group: Hatchery	Test group: Species	Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group: Parr	Transitional	Smolt	Precocious	Total test group
Chelan (Leavenworth)	Steelhead	04-26-79		length[a]	204.3 ± 15.153[c]	220.7 ± 16.021	235.0 ± 18.096	215.8 ± 16.597	226.5 ± 19.032
				weight[b]	78.6 ± 13.741	104.7 ± 25.748	124.9 ± 32.516	107.8 ± 24.915	113.5 ± 31.082
				number	8	84	95	13	200
		06-06-79	41	length	215.5 ± 3.535	229.8 ± 18.919	238.9 ± 15.662	242.6 ± 34.216	235.8 ± 18.249
				weight	89.9 ± 10.747	116.8 ± 36.202	123.1 ± 29.252	146.0 ± 63.780	121.6 ± 33.782
				number	2	33	66	5	106
		07-17-79	41	length	233.3 ± 22.594	245.9 ± 13.468	243.9 ± 16.506		242.0 ± 17.816
				weight	120.4 ± 38.072	145.2 ± 30.913	129.3 ± 32.440		130.8 ± 33.997
				number	16	16	42	0	74
		08-27-79	41	length	238.0 ± 18.118	247.8 ± 16.776	251.5 ± 20.075		247.7 ± 18.837
				weight	114.9 ± 30.772	129.8 ± 39.164	136.0 ± 47.962		129.8 ± 42.030
				number	9	18	22	0	49
		11-20-79	85	length	225.0 ± 0.000	230.7 ± 5.508	275.2 ± 20.753	270.7 ± 27.683	262.9 ± 27.252
				weight	97.0 ± 0.000	112.1 ± 20.775	215.1 ± 72.313	232.8 ± 88.371	191.8 ± 80.138
				number	1	3	9	3	16

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

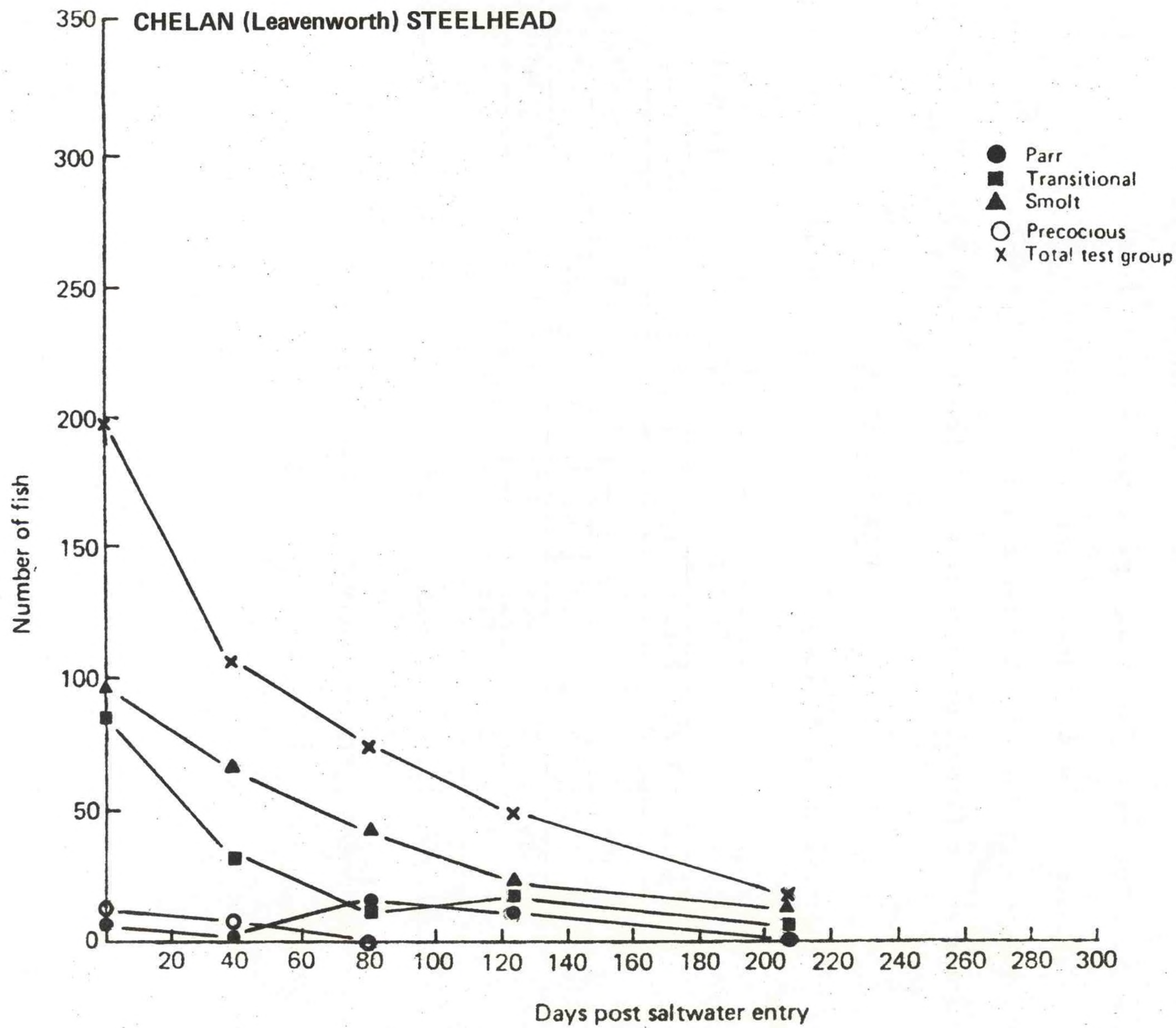


Figure 43.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Wells (Winthrop) Species: Steelhead Stock: Wells

Date of Initial Observation: 05-11-79 Termination Date: 11-20-79 Elapsed Days: 193

Number of Replicates: 1 Total No. of Fish at Start: 200
Total No. of Fish at Termination: 9

Surface Water Temperature at Time of Saltwater entry: No reading Figure: 3

Surface Salinity at Time of Saltwater Entry: No reading Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: No reading Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): No reading Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	46	3	23.0	33.3	55.5	115.4	180.0	236.3
Transitional	97	2	48.5	22.2	90.3	165.8	213.1	251.5
Smolt	56	4	28.0	44.4	120.6	493.7	232.8	349.5
Precocious	1	0	0.5	0.0	58.2		191.0	
Population	200	9	100.0	100.0	90.6	294.7	210.9	290.0

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 43 Figure(s): 44

OVERALL SEAWATER ADAPTATION

COMMENTS

At entry to seawater, Wells steelhead consisted primarily of transitional stage fish, based upon external characteristics. After 24 days of seawater residence, 73% of the fish had died of osmoregulatory dysfunction. Vibriosis accounted for most of the other mortalities for the remainder of the study. The presence of precocious males was not a problem in this test group. Overall mortality rate was 95%.

TABLE 43.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Wells (Winthrop)	Steelhead	05-11-79		length[a/] weight[b/] number	180.0 ± 26.436[c/] 55.5 ± 23.805 46	213.1 ± 22.532 90.3 ± 32.188 97	232.8 ± 29.387 120.6 ± 59.094 56	191.0 ± 0.000 58.2 ± 0.000 1	210.9 ± 31.667 90.6 ± 46.226 200
		06-04-79	24	length weight number	216.8 ± 17.873 97.3 ± 26.830 13	225.8 ± 19.948 108.1 ± 30.268 10	258.0 ± 37.433 170.1 ± 87.539 12	0	233.5 ± 31.729 125.4 ± 63.800 35
		07-17-79	43	length weight number	221.1 ± 17.269 113.4 ± 30.856 17	267.5 ± 31.225 204.7 ± 81.676 4	271.5 ± 37.267 217.2 ± 110.531 8	0	241.4 ± 35.043 154.6 ± 82.594 29
		08-27-79	41	length weight number	212.0 ± 13.910 84.3 ± 19.652 5	242.3 ± 15.854 135.3 ± 28.799 8	307.2 ± 36.928 298.1 ± 109.163 5	0	251.9 ± 43.375 166.4 ± 103.811 18
		11-20-79	85	length weight number	236.3 ± 13.429 115.4 ± 15.519 3	251.5 ± 45.962 165.8 ± 73.186 2	349.5 ± 54.249 493.7 ± 273.567 4	0	290.0 ± 68.070 294.7 ± 254.579 9

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

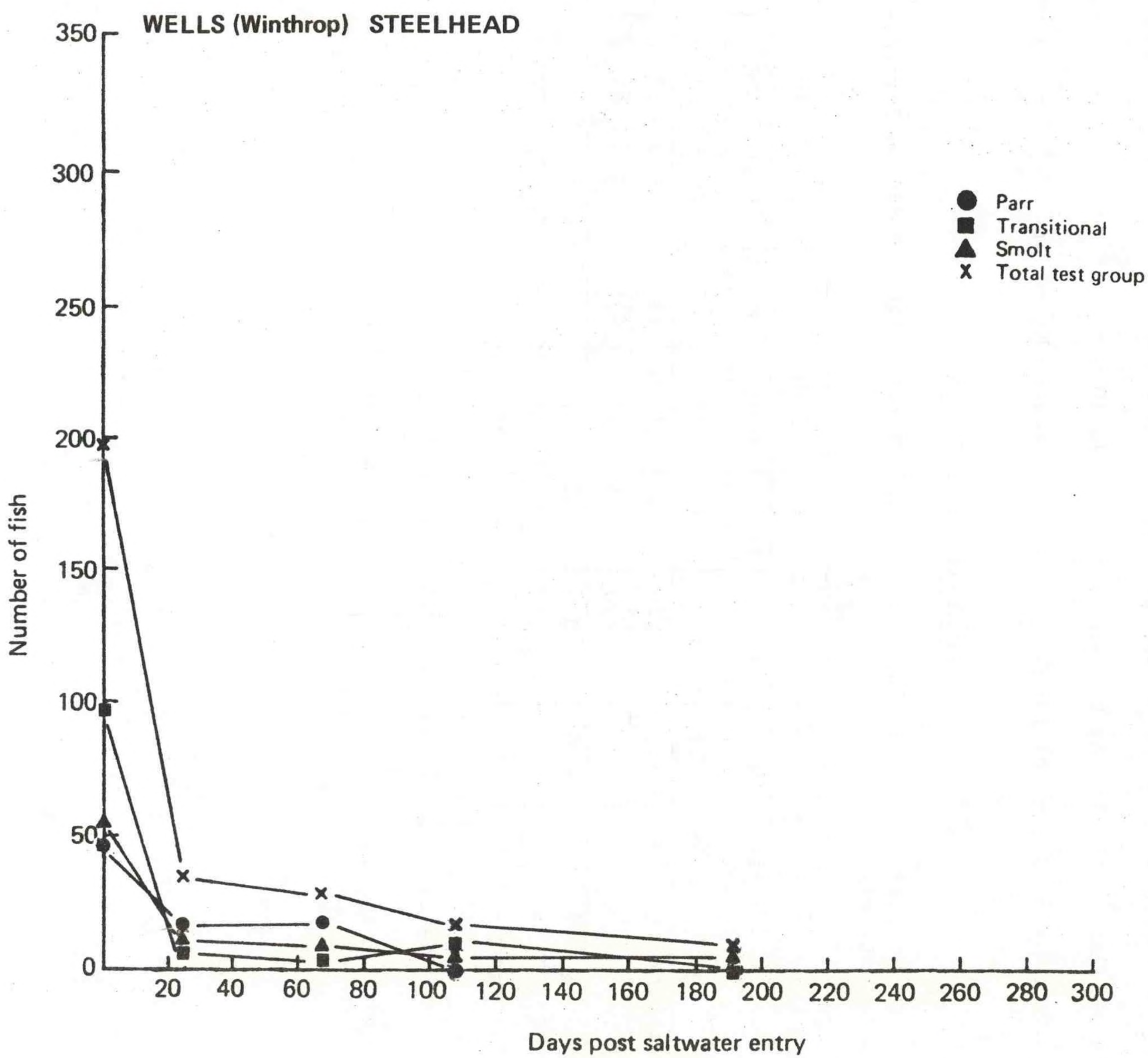


Figure 44.--Number of parred, transitional,and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

TEST GROUP SYNOPSIS

Hatchery: Tucannon   Species: Steelhead   Stock: Skamania

Date of Initial Observation: 05-15-79   Termination Date: 11-19-79   Elapsed Days: 188

Number of Replicates: 1   Total No. of Fish at Start: 200
Total No. of Fish at Termination: 37

Surface Water Temperature at Time of Saltwater entry: 10.0°C   Figure: 3

Surface Salinity at Time of Saltwater Entry: 28.0 °/oo   Figure: 3

Dissolved Oxygen at Time of Saltwater Entry: 12.10 ppm   Figure: 3

Water Transparency (Secchi Disc) at Time of Saltwater Entry (m): 3.3   Figure: 3

SALTWATER ADAPTATION

Status of smoltification at time of entry and at termination based on external characteristics:

	n		%		$\overline{X}$ (Wt) (g)		$\overline{X}$ (L) (mm)	
	Start	End	Start	End	Start	End	Start	End
Parr	38	11	19.0	29.7	27.1	69.9	140.2	192.1
Transitional	30	9	15.0	24.3	40.4	133.9	164.3	232.0
Smolt	132	17	66.0	45.9	45.6	221.3	173.9	276.8
Precocious	0	0	0.0	0.0				
Population	200	37	100.0	100.0	41.3	155.0	166.1	240.7

Saltwater Measurement, Visual Observation, and Disease Data:

Table(s): 2 and 44   Figure(s): 45

OVERALL SEAWATER ADAPTATION

COMMENTS

At seawater entry 66% of the fish were judged to be smolts. After 27 days of seawater residence only 49% of the population survived. Osmoregulatory dysfunction accounted for 19% of the initial mortality. Vibriosis was the pathogen most commonly isolated from moribund fish. A large number of fish (25%) were unaccounted for at the end of testing. The sides of the holding pen had been found in a partially lowered position on several occasions during the study. This condition allowed some of the fish to jump out of the net-pen into a common secondary pen. Other net-pens were noted in the same condition, thus the specific identity of fish found in the secondary net-pen could not be obtained.

TABLE 44.--Length and weight of fish during different stages of development in salt water.

Test group		Dates of observation	Number days between observation	Mean length mean weight no. of fish	Development stage of fish in test group				
Hatchery	Species				Parr	Transitional	Smolt	Precocious	Total test group
Tucannon	Steelhead	05-15-79		length[a]	140.2 ± 12.509[c]	164.3 ± 8.162	173.9 ± 10.221		166.1 ± 16.641
				weight[b]	27.1 ± 6.680	40.4 ± 6.124	45.6 ± 8.073		41.3 ± 10.366
				number	38	30	132	0	200
		06-12-79	28	length	147.1 ± 15.546	171.4 ± 11.673	180.5 ± 12.718		175.8 ± 16.690
				weight	33.2 ± 10.081	49.6 ± 9.169	52.9 ± 10.951		50.3 ± 12.284
				number	11	10	76	0	97
		07-19-79	37	length	167.0 ± 19.538	191.9 ± 10.935	200.7 ± 16.349		188.2 ± 21.647
				weight	48.8 ± 16.116	64.9 ± 15.825	72.1 ± 18.298		63.2 ± 19.545
				number	21	18	30	0	69
		08-27-79	39	length	173.6 ± 20.735	195.9 ± 11.399	223.7 ± 13.834		202.9 ± 25.728
				weight	52.7 ± 18.093	73.0 ± 15.806	103.8 ± 23.695		81.8 ± 29.427
				number	14	16	25	0	55
		11-19-79	84	length	192.1 ± 12.637	232.0 ± 14.705	276.8 ± 20.705		240.7 ± 40.473
				weight	69.9 ± 12.678	133.9 ± 27.222	221.3 ± 67.787		155.0 ± 81.541
				number	11	9	17	0	37

a/ Mean length (mm).

b/ Mean weight (g).

c/ Standard deviation.

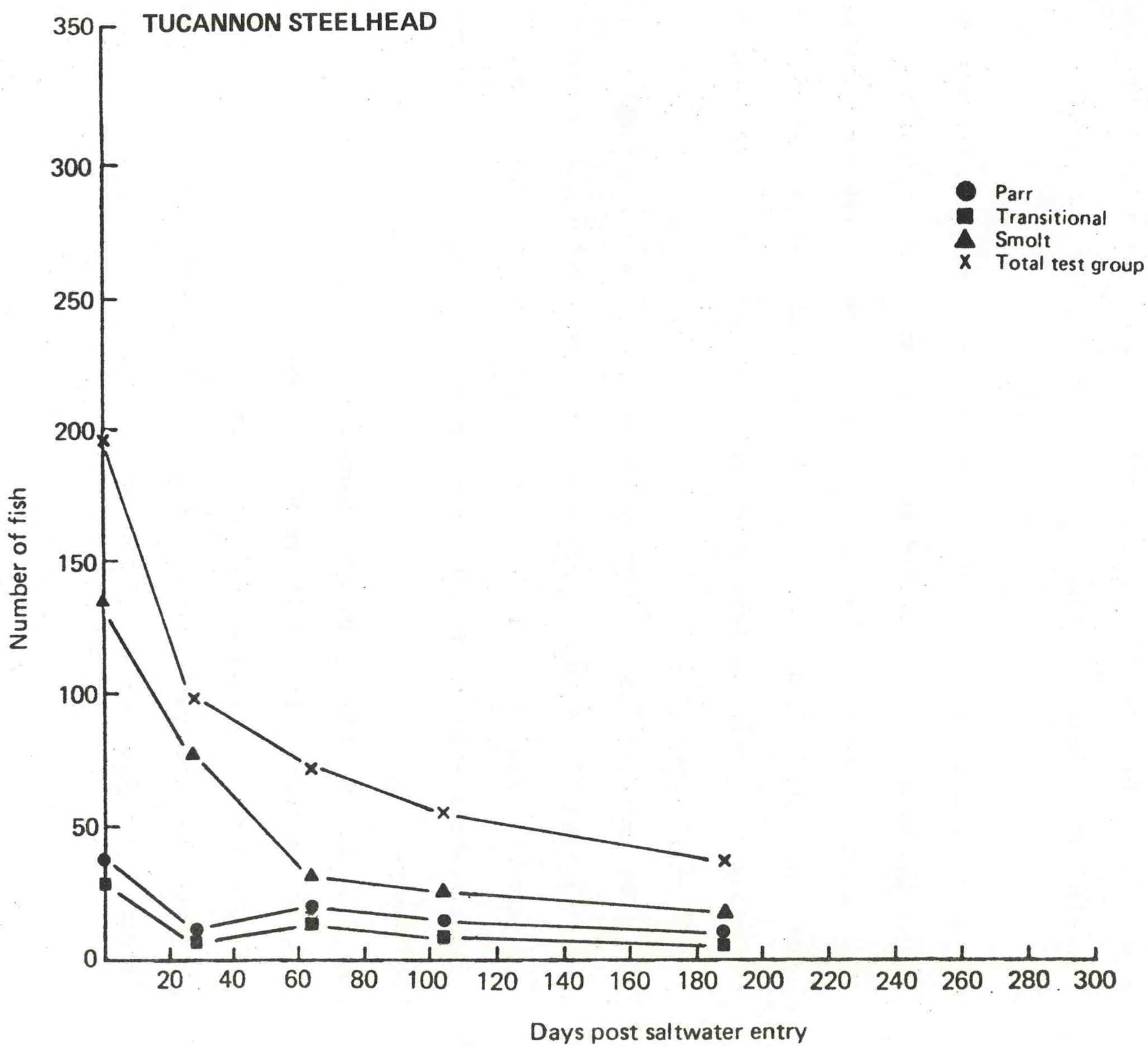


Figure 45.--Number of parred, transitional, and smolted fish (staging based on external characteristics) and total test group survival in seawater vs time.

SUMMARY

As in the 1978 study, each species and test group within the species performed differently in seawater regarding growth, survival, susceptibility to disease, and maturation. The same general trends in the above parameters were present for each species in 1979 as they were in 1978. The performance characteristics on a species basis are summarized in Table 45, followed by a generalized description of the seawater adaptability of each species.

Coho Salmon

Coho salmon serially released from Toutle, Washougal, Cascade, and Big Creek Hatcheries were evaluated as to their seawater adaptability in 1979. The hatcheries released their fish on the same day of the month during May, June, and July. Each hatchery manager adjusted feed regimes so that fish released from that hatchery were about the same size regardless of the month of release.

The mortality rate generally increased for each consecutive seawater entry period (Table 46). There appeared to be a relationship between time of direct seawater entry, survival, and size of the fish. These relationships will be investigated further as additional information is obtained.

As in the 1978 study, the percent of smolted fish increased by the second observation period (40 to 60 days post seawater entry). A decrease in the number of transitional and parr fish took place during the same period. This decrease indicated that the parr-smolt transformation process based on external characteristics was continuing in seawater.

Table 45.--Summary of seawater performance of chinook and coho salmon and steelhead.

	Fish			
Parameter	Coho	Steelhead	Spring chinook	Fall chinook
Initial loss due to osmoregulatory stress	Low: Coho that are unready for long-term adaptation to seawater can generally survive for 30 days or more.	Potentially high: Fish size doesn't seem as important as physiological status. Possibly exacerbated by latent freshwater pathogenic organisms and ambient freshwater and seawater temperatures.	Potentially high (>30%): Smaller fish may die due to osmoregulatory dysfunction if there are no peaks in physiological profiles prior to transfer to seawater.	Potentially high: Fish weighing less than 5 g (spring to mid-summer) or 10 g (after mid-summer) may die due to osmoregulatory dysfunction if there are no peaks in physiological profiles prior to introduction to seawater.
Reversion to nonsmolted condition	Likely to occur in substantial proportions (>40%) if there are no peaks in physiological profiles immediately prior to seawater transfer.	Likely to occur in substantial proportions among smaller fish if there are no peaks in physiological profiles immediately prior to seawater transfer. It seems that freshwater and seawater temperatures in excess of 12°C can inhibit some physiological smoltification processes and therefore may influence percent reversion to a nonsmolted condition.	Two patterns have been observed: 1) reversions seldom occur in test groups introduced to seawater in the spring to mid-summer because potentially susceptible--i.e., small-fish die due to osmoregulatory problem and 2) the smaller fish in test groups introduced to seawater after mid-summer can show long-term retention of parr and transitional characteristics.	Low: Small fish die due to osmoregulatory stress, however, some reversions occur, with the incidence of reversions higher in test groups entering seawater after mid-summer.
Growth	Directly related to the parr/smolt ratio: An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Directly related to the parr/smolt ratio: An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Good: Most of the slower growing--i.e., small--fish have been eliminated from the test groups by osmoregulatory dysfunction; however, in groups entering seawater after mid-summer the growth can be related to the parr/smolt ratio. An increase in the percent of parred fish will result in a corresponding decrease in the mean growth of the test group.	Fair: Some of the slow growing--i.e., small--fish eliminated by osmoregulatory dysfunction; therefore, the growth can be related to the parr/smolt ratio. An increase in the percent of parred fish will result in corresponding decrease in the mean growth rate of the test group.
Resistance to vibriosis (determined by unvaccinated/vaccinated ratio)	Good: Losses start occurring after 50 days with most losses occurring after 120 days of seawater residence.	Fair: Losses start occurring approximately 10 days after transfer to seawater. The ability to provide immune defense against vibriosis may be related to the degree of infection by overt and latent freshwater pathogenic organisms.	Fair: Losses start approximately 15 days after transfer to seawater.	Fair: Losses start approximately 15 days after transfer to seawater.
Total mortality	Nonsmolts die from 5 to 9 months after seawater entry; therefore, total mortality depends on percent parr and severity of <u>Vibrio</u> outbreaks. Freshwater disease history also is important in determining overall seawater survival.	Long term osmoregulatory mortalities occur concurrent with losses due to vibriosis.	Total mortality may be substantial, with the initial losses due to osmoregulatory dysfunction followed by losses due to vibriosis.	Total mortality may be substantial, with the initial losses due to osmoregulatory dysfunction followed by losses due to vibriosis.
Precocious males	Low incidence but when present, precocious males are the larger fish in the population at seawater entry.	Low incidence.	Precocious males may comprise up to 8% of the fish in the test group. Precocious males usually are the larger fish in the population at seawater entry.	Low incidence.

Table 46.--Mortality rate for coho salmon test groups after 60 days of seawater residence for 1979.

Test group	Entry group	Seawater entry	Number at start	% Mortality per day
Big Creek	1	9 May 1979	200	0.06
Cascade	1	8 May 1979	200	0.03
Toutle	1	9 May 1979	200	0.08
Washougal	1	9 May 1979	200	0.11
Big Creek	2	10 June 1979	200	0.06
Cascade	2	10 June 1979	200	0.17
Washougal	2	10 June 1979	200	0.26
Toutle	2	16 June 1979	200	0.12
Big Creek	3	10 July 1979	200	0.16
Cascade	3	10 July 1979	200	0.16
Toutle	3	10 July 1979	200	0.35
Washougal	3	10 July 1979	200	0.30

Reversion from a smolt to transitional and/or parr was observed after about 70 days in seawater. The reversions were evident in all test groups and continued to the end of the study.

Total mortality was minimal for about the first 40 days of seawater residence. Thereafter, disease (primarily vibriosis) and losses due to osmoregulatory-related problems increased. The test groups containing the highest percentage of parred fish at seawater entry generally experienced the greatest mortality. As in the past, smolted fish were the most susceptible to vibriosis.

No precocious males were observed in the coho salmon test groups for 1979.

Baseline Coho Salmon

Yearling coho salmon (Toutle Stock) were reared under known conditions at the NMFS laboratory in Seattle. The fish were designated as a baseline study group. Fish from the group were transferred to seawater on 10 occasions from March to September 1979. The initial number of smolts in each test group being transferred to seawater increased to early May (fifth entry group), was relatively constant between groups from the end of May through June, and then decreased in the late entry groups. Once the fish were in seawater the number of smolts in a test group increased, whereas the inverse was true for transitional and parr stage fish. The smoltification process (based on external characteristics) appears to continue when fish are placed in seawater.

Peak smoltification appeared about the time of the fifth entry. However, while the fish were in fresh water, furunculosis developed just before the fifth entry period; however, it was corrected by the sixth. The fish in the fifth group were apparently weakened by the disease--thus they showed a higher mortality rate in seawater than either the fourth or sixth group (Table 47). Few fish reverted from a smolted condition back to a transitional or parred condition.

Mortalities directly associated with osmoregulatory dysfunction were not identifiable. Many fish, however, showed no evidence of pathogens upon examination, suggesting that osmoregulatory problems may have caused the mortality.

Vibrio anguillarum was the main pathogen isolated from the ten entry groups. This pathogen was not isolated until a group of fish had been exposed to seawater for several months in most cases. This is, in part, reflected in the low mortality rate of the tenth entry group.

Spring Chinook Salmon

Spring chinook salmon showed a high percent of precocious males (0 to 15% depending upon test group and period of observation). Precocious males died after several months of seawater residence and were generally the larger fish of the initial population.

Vibriosis was the major cause of mortality, commencing within 12 days of seawater residence among nonvaccinated fish. At termination, 41% and 52% of the fish vaccinated survived in the Carson and Leavenworth test groups, respectively, vs 0% and 22%, respectively, for the unvaccinated fish. In noncaptive fish, it is presumed that vibriosis would not be the problem that it is in a captive situation such as seawater net-pens. The mortality rate after 60 days of seawater residence was 0.60 and 0.28%/day for Carson and Leavenworth test groups, respectively. The higher mortality

Table 47.--Mortality rate for baseline coho salmon groups after 60 days of seawater residence for 1979.

Test group	Entry group	Seawater entry	Number at start	% Mortality per day
Toutle	1	21 March 1979	150	0.17
Toutle	2	3 April 1979	150	0.16
Toutle	3	17 April 1979	150	0.04
Toutle	4	1 May 1979	150	0.00
Toutle	5	15 May 1979	149	0.12
Toutle	6	30 May 1979	150	0.02
Toutle	7	12 June 1979	150	0.09
Toutle	8	24 July 1979	150	0.28
Toutle	9	21 August 1979	150	0.43
Toutle	10	18 September 1979	150	0.12

rate for Carson fish was, in part, associated with the higher percentage of precocious males within the test group.

Fall Chinook Salmon

Size, time, and status of smoltification are among the factors determining initial survival of fall chinook salmon introduced directly to seawater. Initial mortality upon seawater entry is normally related to osmoregulatory dysfunction. Osmoregulatory problems affect the smaller nonsmolted fish in a population. Fish suffering this problem show signs of severe dehydration (rippling of the skin). Mortality directly associated with osmoregulatory dysfunction usually occurs within the first 10 to 15 days of seawater residence. However, the problem can be detected over extended periods. Vibriosis accounts for most of the mortalities not directly associated with osmoregulation (Table 48).

In general, the test groups with a larger mean weight at time of seawater entry had a greater overall survival and a higher percentage of smolted fish than test groups with a smaller mean weight. This, however, seems dependent upon the freshwater disease history and rearing environment. Unfortunately, insufficient data exist at present to elaborate at this time.

Based upon the information collected on fall chinook salmon over the past several years, it now appears that holding the fish about 30 days in seawater will provide much of the information needed to assess seawater adaptation. However, some data will be lost following this procedure. For instance, data related to the occurrence of BKD and vibriosis would be limited. Both of these pathogens normally do not manifest themselves in fall chinook salmon until well over a month of seawater exposure, thus data

Table 48.--Mortality rate for fall chinook salmon test groups after 60 days of seawater residence for 1979.

Test group	Entry group	Seawater entry	Number at start	% Mortality per day
Willard	1	12 July 1978	300	0.44
Willard	2	1 November 1978	300	0.52
Bonneville (late yearlings)	1	20 March 1979	300	0.21
Spring Creek	1	22 March 1979	300	0.66
Spring Creek	2	21 April 1979	300	0.35
Willard	3	21 April 1979	300	0.49
Big White Salmon	1	22 May 197979	150	0.13
Spring Creek	3	22 May 1979	300	0.35
Bonneville (1978 brood)	1	31 May 1979	300	0.35
Washougal	1	15 June 1979	300	0.39
Elokomin	1	15 June 1979	300	0.17
Little White Salmon	1	27 June 19799	301	0.48
Toutle	1	27 June 1979	133	0.49
Kalama Falls	1	19 July 1979	300	0.91
Spring Creek	4	14 August 1979	300	0.18

regarding the occurrence of or susceptibility to these pathogens would be missing.

Steelhead

Mortalities related to osmoregulatory dysfunction occurred throughout the study. However, it became increasingly difficult to detect such mortalities because of bacterial infections as the study progressed. In those mortalities showing no infection, it was presumed to be osmoregulatory related; however, viral or other problems may have caused the deaths.

The overall survival of steelhead in seawater was poor despite the apparent high number of smolts (visual criteria). The fish were apparently not fully smolted from a physiological standpoint at seawater entry, or seawater temperature caused a blockage or reversion of the smoltification process. Mortalities from Vibrio Strains 775, 1669, and 7244 also occurred throughout the study with Strain 775 being the most prevalent. The mortality rates after 60 days of seawater residence are shown in Table 49.

In 1979 as in 1978, steelhead showed a loss of a silvery smolt appearance followed by a noticeable external darkening--the condition was not associated with precociousness. A separate study was conducted to monitor the above condition (Appendix C).

Table 49.--Mortality rate for steelhead test groups after 60 days of seawater residence for 1979.

Test group	Entry group	Seawater entry	Number at start	% Mortality per day
Chelan (Leavenworth)	1	26 April 1979	200	0.81
Wells (Winthrop)	1	11 May 1979	200	1.42
Tucannon	1	15 May 1979	200	0.62

APPENDIX C

INFLUENCE OF SEAWATER TEMPERATURE ON SURVIVAL, STATUS OF SMOLTIFICATION, AND EXTERNAL DARKENING OF STEELHEAD

By

Kurt X. Gores

and

Earl F. Prentice

September 1980

INTRODUCTION

During the 1978 PNRC Smolt Study, a high incidence of external darkening was observed in steelhead test groups held in seawater. The incidence of darkening was positively related to the seasonal increase and decrease of seawater temperature. This darkening may be an indication of physiological stress and may help explain the overall poor survival of the 1978 steelhead test groups. Water temperature has been associated with changes in both behavior and biochemical activity. Steelhead have shown impaired migratory behavior and reduced gill Na^{+}-K^{+}ATPase activity (reversion to parr) when raised in freshwater above 12°C (Zaugg et al. 1972; Zaugg and Wagner 1973).

METHODS AND MATERIALS

In 1979, a test was conducted to monitor the effect of seawater temperature on survival, status of smoltification (determined by external characteristics), and the incidence of external darkening. A group of 200 yearling Tucannon steelhead was equally divided and placed in four 4-foot diameter circular tanks. Running seawater in two of the tanks was chilled (<12°C) while water in the other two tanks was supplied at near-ambient temperatures (10.0-16.5°C). Water in all tanks was aerated. Comparison was made to a test group held in a seawater net-pen located in Clam Bay where water temperatures ranged from 9.3-15.3°C. Fish were observed from mid-May through mid-November. Salinity ranged from 28.0-30.5%.

RESULTS AND DISCUSSION

Results showed an inverse relationship between survival and rearing temperature (Table 1). There was also a higher incidence of external darkening in fish reared in near-ambient water than fish reared in either

Table 1.--Percent survival, status of smoltification, and color of steelhead reared at various seawater temperatures.

Date	% Survival n	% Survival %	% Parr	% Transitional	% Smolt	% Dark	Mean seawater Temperature (^{o}C) for test period
				AMBIENT			
5/15/79	100	100.0	18.0	16.0	66.0	0.0	
							12.5
6/12/79	48	48.0	22.9	25.0	52.0	14.6	
							13.6
7/19/79	21[a/]	70.0	23.8	57.1	19.0	52.4	
							14.4
8/27/79	20	66.7	30.0	45.0	25.0	45.0	
							13.4
11/19/79	5	16.7	20.0	60.0	20.0	20.0	
				NET-PEN			
5/15/79	200	100.0	19.0	16.0	66.0	0.0	
							11.7
6/12/79	97	48.5	11.3	13.4	78.4	10.3	
							12.6
7/19/79	69	34.5	30.4	27.3	43.5	26.1	
							13.4
8/27/79	55	27.5	25.5	15.8	45.5	25.4	
							12.8
11/19/79	37	18.5	29.7	33.3	46.0	18.9	
				CHILLED			
5/15/79	100	100.0	20.0	15.0	63.0	0.0	
							8.8
6/12/79	67	67.0	10.4	10.3	76.1	1.5	
							9.9
7/19/79	44	44.0	31.8	26.1	40.9	15.9	
							10.1
8/27/79	38	38.0	36.8	29.1	47.4	26.3	
							9.4
11/19/79	30	30.0	50.0	24.3	16.7	33.3	

a/ Water failure caused one replicate to be terminated 7/13/79. The percent survival was based upon n = 30 from the time of failure on.

chilled water or the net-pen until the fourth and fifth measurements (Table 1). There were generally fewer smolts observed in the ambient tanks than the chilled tanks or net-pen until the fifth measurement (Table 1).

Water failures, affecting the chilled tanks, occurred with increasing frequency as the study progressed. Although the mean temperature in the chilled tanks exceeded 12°C for only one day, the reduced flow caused fluctuations in water temperature and dissolved oxygen that may have imposed a series of stresses on the fish. Toward the end of the study (Measurements 4 and 5) these stresses may have had a greater effect on external darkening and status of smoltification than water temperature alone.

As in freshwater, rearing temperature in seawater apparently affects the smolting process. When rearing temperatures exceed 12°C, reduction in gill Na^{+}-K^{+} ATPase may occur resulting in reversion to parr. Non-captive steelhead can avoid surface water or thermal strata above 12°C; however, the results of this test can be applied to net-pen rearing facilities where seasonal seawater temperatures exceed 12°C.

LITERATURE CITED

Zaugg, W. S., B. L. Adams, and L. R. McLain.
1972. Steelhead migration: potential temperature effects as indicated by gill adenosine triphosphatase activities. Science 176:415-416.

Zaugg, W. S., and H. H. Wagner.
1973. Gill ATPase activity related to parr-smolt transformation and migration in steelhead trout (Salmo gairdneri): influence of photoperiod and temperature. Comp. Biochem. Physiol. 45B, 955-965.

APPENDIX D

FISH HEALTH, A GENERAL EVALUATION

by

Lee. W. Harrell

and

Anthony J. Novotny

September 1980

INTRODUCTION

During 1979, National Marine Fisheries Service (NMFS) personnel at the Manchester Marine Experimental Station documented the health status of the target stocks in both fresh and seawater.

A. Examination of hatchery rearing records.

   Wherever possible, data concerning the culture and treatment of fish (Table 1) were collected from hatchery managers.

B. Determination of health at the time of transport to the marine environment.

   This evaluation consisted of basic hematology and the identification of bacterial kidney disease (BKD) organisms in kidney tissue samples as an indication of disease. These tests were performed on 60-fish subsamples from the fish transported to Manchester for saltwater evaluation (Table 2).

C. Monitoring mortality after transfer to marine net-pens for extended culture.

   After transfer to marine net-pens, fish mortalities were collected daily, necropsies performed, and attempts made to isolate bacterial pathogens on appropriate culture media.

METHODS AND MATERIALS

Hatchery Records

Records were obtained from the hatcheries and pertinent information regarding the culture of the fish was documented. This information included: diets, environment, diseases and treatment, total mortality, size of fish at release, and date of release. In cases where fish populations were released on several dates, the life history data apply up to the last serial release. Table 1 is a synopsis of collected hatchery data.

Table 1.--Disease and life history of hatchery juveniles.

Hatchery	Stock	Agency[a/]	Species	Date egg take	Date ponded	Feed[b/]	Water source	Water temp °F	Disease(s)[c/]	Medication[d/]
Kalama Falls	Kalama Falls	WDF	Fall chinook	Oct/78	Mar/79	OMP	Kalama River	53-60	Costia (May-June/79) BHS (Jun/79) BGD (Jun/79) BHS (Jul/79)	Formalin Sulmet-TM-50 Diquat Sulmet
Toutle	Green River	WDF	Fall chinook	Sep/78	e/	e/	e/	e/	e/	
Bonneville	Bonneville	ODFW	Fall chinook	Sep/78	Jan/78	OMP	Tanner Creek + Ground Water	44-52	BGD (Mar/78) Fungus (Mar/78)	Hyamine $KMnO_4$ & MG
Bonneville	Bonneville	ODFW	Fall chinook	Sep/78	Dec/78-Jan/79	OMP	Tanner Creek + Columbia River	47-55	Costia (Mar-May/79) Fungus (May/79)	Formalin MG
Little White Salmon	Little White Salmon	USFWS	Fall chinook	e/	e/	OMP	River	40-50	Costia (Mar/79) Hexamita (May/79)	Formalin
Spring Creek	Spring Creek	USFWS	Fall chinook	e/	e/	OMP & ABERN	Ground Water	46-50	ERM	None
Spring Creek	Spring Creek	USFWS	Fall chinook	e/	e/	OMP & ABERN	Ground Water	46-50	ERM (Feb/79)	None
Spring Creek	Spring Creek	USFWS	Fall chinook	e/	e/	OMP & ABERN	Ground Water	46-50	ERM (Feb/79) Gill Ameoba (May/79)	None
Spring Creek	Spring Creek	USFWS	Fall chinook	e/	e/	OMP & ABERN	Ground Water	46-50	ERM Gill Amoeba	Roccal June 6-8 Salt June 11 Formalin June 4
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	e/	e/	e/	
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	e/	e/	e/	
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	e/	e/	e/	
Big White Salmon	Spring Creek	USFWS	Fall chinook	e/	e/	OMP & ABERN	Ground Water	42-52	ERM (Feb/79)	TM-50 Feb/79
Elokomin	Elokomin	WDF	Fall chinook	e/	e/	e/	e/	e/	e/	
Washougal	Toutle	WDF	Fall chinook	e/	Sep-Oct/78	OMP	River	54-72	Costia; ICH FURUNC-COLUMN	25 ppm Formalin TM-50

Table 1.--cont.

Hatchery	Stock	Agency[a]	Species	Mortality (all causes) (%)	Size at release (no./lb)	Date released	Date transfer to Manchester	Comments
Kalama Falls	Kalama Falls	WDF	Fall chinook	16.0	172.0	July 13, 1979	July 16, 1979	Some fungus on fins at time of release
Toutle	Green River	WDF	Fall chinook	e/	e/	June 27, 1979	June 22, 1979	
Bonneville	Bonneville	ODFW	Fall chinook	41.0	e/	May, June, October 1978 & March 1979	March 15, 1979	BGD major cause of losses
Bonneville	Bonneville	ODFW	Fall chinook	7.0	e/	May, June, October 1979 & March 1980	May 29, 1979	
Little White Salmon	Little White Salmon	USFWS	Fall chinook	3.2	e/	June 22, 1979	June 22, 1979	Fish were small at release
Spring Creek	Spring Creek	USFWS	Fall chinook	1.4	153.0	March 20, 1979	March 20, 1979	Very slight mortality from ERM
Spring Creek	Spring Creek	USFWS	Fall chinook	2.5	78.0	April 20, 1979	April 19, 1979	General health good
Spring Creek	Spring Creek	USFWS	Fall chinook	3.1	52.0	May 18, 1979	May 18, 1979	Slight ERM mortality
Spring Creek	Spring Creek	USFWS	Fall chinook	2.6	14.0	August 13, 1979	August 10, 1979	General fish health fair ERM + gill amoeba treatment unsuccessful
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	July 10, 1978	
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	October 30, 1978	
Willard	Little White Salmon	USFWS	Fall chinook	e/	e/	e/	April 19, 1979	
Big White Salmon	Spring Creek	USFWS	Fall chinook	7.6	69.0	May 21, 1979	May 18, 1979	ERM losses greatest after transfer from Spring Creek
Elokomin	Elokomin	WDF	Fall chinook	e/	e/	June 15, 1979	June 13, 1979	
Washougal	Toutle	WDF	Fall chinook	15.0	80.0	June 15, 1979	June 13, 1979	

Table 1.--cont.

Hatchery	Stock	Agency[a/]	Species	Date egg take	Date ponded	Feed[b/]	Water source	Water temp °F	Disease(s)[c/]	Medication[d/]
Carson	Carson	USFWS	Spring chinook	Aug/77	Jan/78	OMP & ABERN	Spring + River	41-52	BKD	None
Leavenworth	Leavenworth	USFWS	Spring chinook	Jan/78	May-Jun/78	OMP & ABERN	River	38-57	BGD (Jul-Aug/78)	Purina 4X Hyamine 1622
Montlake	Toutle	WDF	Coho	Oct-Nov/77	Jan/78	OMP	Seattle City Water	38-64	Myxobacteria (Nov/78) Furunculosis (May/79) Furunc (June/80)	TM-50 Chloramphenicol Chloramphenicol
Washougal	Cowlitz	WDF	Coho	Feb/78	Apr/78	OMP	River	47-54	CWD Coagulated yolk	TM-50, Furanace March 25/78
Big Creek	Big Creek	ODFW	Coho	Nov/77	Jan/78	OMP	Creek	48-60	e/	
Cascade	Sandy	ODFW	Coho	Oct-Nov/77	Mar/78	e/	e/	e/	CWD (Apr/78) Costia (Jun/78) CWD (Nov/78)	TM-50 3% Formalin TM-50 12
Toutle	Green River	WDF	Coho	Oct-Nov/77	e/	OMP	Green River	44-61	Costia (Feb 21/78) Costia (Apr 14/78) Costia (Jun 14/78) FURUNC (Jul 28/78) ICH (Aug/78) COLUMN	Formalin 1:6000 TM-50 12 days Formalin Drip TM-50 12 days
Tucannon	Skamania	WDG	Steelhead	e/	e/	Clarke's S.C. OMP	e/	40-62	Octomitus COLUMN ICH (May-Sep/78)	MG NF-180 diet Diquat TM-50-Sulfa Formaldehyde drip
Leavenworth	Chelan	WDG	Steelhead	e/	e/	OMP & ABERN	River	34-56	BGD (Apr/78) Epistylus (Jul/78)	Purina 4X Formalin 1:600
Winthrop	Wells	WDG	Steelhead	e/	e/	S.C. Clarke's OMP-2	e/	e/	None	None

Table 1.--cont.

Hatchery	Stock	Agency[a]	Species	Mortality (all causes) (%)	Size at release (no./lb)	Date released	Date transfer to Manchester	Comments
Carson	Carson	USFWS	Spring chinook	47.0	16.5	May 2, 1979	May 1, 1979	
Leavenworth	Leavenworth	USFWS	Spring chinook	15.5	20.0	April 26, 1979	April 25, 1979	
Montlake	Toutle	WDF	Coho	e/	e/	No release	March-September, 1979	
Washougal	Cowlitz	WDF	Coho	39.3	18.0	May-July, 1979	May-July, 1979	Heavy mortality at time of ponding
Big Creek	Big Creek	ODFW	Coho	3.1	18.0	May-July, 1979	May-July, 1979	
Cascade	Sandy	ODFW	Coho	7.9	22.0	May-July, 1979	May-July, 1979	
Toutle	Green River	WDF	Coho	e/	18.0	May-July, 1979	May-July, 1979	
Tucannon	Skamania	WDG	Steelhead	22.0	e/	e/	May 14, 1979	
Leavenworth	Chelan	WDG	Steelhead	15.4	12.0	April 26, 1979	April 25, 1979	
Winthrop	Wells	WDG	Steelhead	e/	e/	May 9, 1979	May 10, 1979	

a/ USFWS-U.S. Fish and Wildlife Service; WDF-Washington Department of Fisheries; ODFW-Oregon Department of Fish and Wildlife, WDG-Washington Department of Game.

b/ OMP-Oregon Moist Pellet; ABERN-Abernathy; S.C.-Silver Cup; Clarke's - Clarke's dry diet.

c/ BGD-Bacterial gill disease; ERM-Enteric red mouth; CWD-Cold water disease; FURUNC-Furunculosis (*Aeromonas salmonicida*); COLUMN-Columnaris disease (*Chondrococcus columnaris*); ICH-Ichthiophthirius infestation; BHS-Bacterial hemorrhagic septicemia; BKD-Bacterial kidney disease.

d/ TM-50-Oxytetracycline in diet form; $KMnO_4$-Potassium permaginate; MG-Malachite green; NF-180-nitrofurazone.

e/ Data not available.

Table 2.--1979 Summarized data for 60 fish subsamples collected for health surveys.

Hatchery	Species	Group no.	Date arrived Manchester	Hematocrit (% packed cell volume) N	Hematocrit X̄	Hematocrit SD	Hemoglobin (mg/dcl) N	Hemoglobin X̄	Hemoglobin SD	Percent of fish positive for BKD
Mont. Toutle	Coho	01	3-15-79	60	34.5	4.3	60	5.6	1.2	a/
" "	"	02	3-29-79	59	36.8	4.5	60	6.2	0.9	a/
" "	"	03	4-13-79	60	36.8	4.2	60	7.1	1.0	a/
" "	"	04	4-27-79	60	40.5	4.1	60	8.1	0.6	a/
" "	"	05	5-11-79	60	51.9	8.1	60	9.4	1.2	a/
" "	"	06	5-25-79	60	41.4	8.0	60	7.5	1.1	a/
" "	"	07	6-8-79	60	54.6	7.2	60	9.9	0.9	a/
" "	"	08	7-20-79	60	37.9	6.0	60	6.3	1.0	a/
" "	"	09	8-16-79	60	33.9	3.9	60	4.6	0.7	a/
" "	"	10	9-16-79	32	34.4	4.9	60	5.3	1.0	a/
Big Creek	"	01	5-7-79	60	35.3	4.8	60	6.8	1.1	a/
" "	"	02	6-7-79	N O T	S A M P L E D					
" "	"	03	7-6-79	55	48.9	5.2	59	7.8	1.1	1.7
Cascade	"	01	5-7-79	56	38.1	5.6	60	6.7	1.3	8.3
"	"	02	6-7-79	60	44.3	7.3	60	7.3	1.2	6.7
"	"	03	7-6-79	59	46.7	7.4	60	6.7	0.9	18.3
Toutle River	"	01	5-7-79	60	36.5	4.5	60	6.5	0.8	a/
" "	"	02	6-3-79	60	45.6	6.8	60	6.1	0.7	a/
" "	"	03	7-6-79	59	40.7	7.1	60	6.1	1.2	6.7
Washougal	"	01	5-7-79	51	35.9	8.0	60	7.4	1.4	a/
"	"	02	6-7-79	58	40.0	8.7	60	5.0	1.4	a/
"	"	03	7-6-79	60	44.1	9.1	60	6.6	1.3	8.3
Big White Salmon	Fa Ch	01	5-18-79	59	43.6	4.8	60	1.0	0.8	8.3
Bonneville	"	01	3-15-79	60	36.4	5.7	60	5.9	1.4	a/
"	"	02	5-20-79	60	46.1	5.1	60	6.5	0.8	23.3
Spring Creek	"	01	3-20-79	N O T	S A M P L E D		57	7.2	0.7	a/
" "	"	02	4-19-79	57	40.3	3.8	51	7.8	0.7	1.7
" "	"	03	5-18-79	59	40.4	9.6	59	7.9	0.7	a/
" "	"	04	8-10-79	60	43.4	4.5	60	7.0	0.7	a/
Willard	"	01	4-19-79	60	26.5	8.8	60	3.2	1.3	56.7
Elokomin	"	01	6-13-79	56	34.9	4.1	58	7.9	1.3	6.7
Washougal	"	01	6-13-79	60	42.5	4.5	60	6.9	0.8	5.0
Kalama Falls	"	01	7-16-79	56	41.7	3.7	60	5.6	0.7	11.7
Little White Salmon	"	01	6-22-79	48	35.4	3.4	60	5.5	1.1	3.3
Carson	Sp Ch	01	5-01-79	60	36.7	10.1	60	5.2	1.8	33.3
Leavenworth	"	01	4-25-79	58	46.3	9.8	58	6.5	1.6	21.7
Chelan	Stld	01	4-25-79	60	49.8	7.7	60	8.9	1.6	1.7
Wells	"	01	5-10-79	58	50.8	6.9	60	9.6	1.1	3.3
Tucannon	"	01	5-14-79	60	53.0	7.7	60	9.2	1.3	1.7

a/ No assay.

Health at Time of Transport to Marine Environment

Sampling

The number of fish sampled for health profiles was based on the work of Ossiander and Wedemeyer (1973), who show that a single disease incidence of 5% or greater can be detected with a sample of 60 fish from populations of 100,000 individuals provided the detection method is accurate. Within 24 h after arrival at Manchester, health survey subsamples of at least 60 fish were drawn from the transported population and held in circular tanks with running ambient creek water.

Assay for BKD

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

The individually indentified fish were opened ventrally and the kidney exposed. Thin smears of anterior and posterior kidney tissue were made on multi-spot slides after piercing the kidney with a sterile inoculation loop. The slides were air-dried and fixed in reagent grade acetone for 10 min. The acetone fixed slides were stored at -20°C until they were examined. Prior to the sampling season, 40 positive control slides were prepared in the same manner and stored at -20°C. The control slides were prepared from a kidney lesion from a spring chinook salmon from Carson National Fish Hatchery (NFH) that was tested and confirmed to have high numbers of pure BKD organisms.

The IFAT for BKD was originally described by Bullock and Stuckey (1975) and later modified by G. W. Camenisch of the U.S. Fish and Wildlife Service (FWS), Eastern Fish Disease Laboratory. A more detailed description of the methods and material used in this assay is found in Appendix C of the 1978 report to the Pacific Northwest Regional Commission (PNRC) (Project 817).

Basic Hematology

Basic hematology was restricted to analyses of hematocrits and hemoglobins. The fish were lightly anesthetized in an aerated MS-222 solution (1:20,000). In most cases, blood was sampled from the caudal arch with a 1 cc syringe and 25 gauge hypodermic needle. Small fish were bled by severing the caudal peduncle and collecting the blood in appropriate capillary tubes. All syringes and capillary tubes were precoated with ammonium heparin to prevent clotting.

Whole blood smears were made on microscope slides which were then labelled, air-dried, stained in Diff-Quick; oven-dried overnight at 45°C; and permanently mounted for future reference. Blood samples taken for hematocrits were centrifuged in microhematocrit tubes at 10,000 RPM for 3 min, read, and recorded as the percent of packed cell volume.

Hemoglobin values were either read directly with an A-O hemoglobinometer or blood was collected in 20 μl capillary tubes for colorimetric analysis. The 20 μl tubes were placed in screw-top test tubes containing 5.0 ml of Drabkins reagent (cyanomethemoglobin) and agitated until the blood was dissolved. Reacted samples were allowed to stand for at least 10 min, decanted into cuvettes, and the absorbance was read at 540 nm against a Drabkin's reagent blank on a B&L Spectronic 20. Calibration curves were prepared from hemoglobin (human) standards. The final data for hematocrits and hemoglobins (Table 2) were frequently based on sample sizes of less than 60 fish due to capillary tube breakage.

Mortality from Disease After Transfer to Seawater Net-Pens

Vaccination

Prior to moving a test group to the seawater net-pens for extended culture, one-half of the population was vaccinated (the other half was fin-clipped to aid in identification and to equalize handling treatment). Inoculum (0.15 ml) was injected into the peritoneal cavity while the fish were anesthetized. The inoculum consisted of the following combination of antibacterials and biologics:

Agent	Amount/fish
oxytetracycline	95.5 μg
nitrofurazone	75.0 μg
heat-killed antigen-*Vibrio anguillarum* (type 775)	900.0 μg
heat-killed antigen-*Vibrio anguillarum* (type 1669)	300.0 μg

The components were diluted in sterile 0.85% NaCl solution.

By combining the antibacterials with the vaccine, we were able to transfer the fish to seawater within 24 h after vaccination. The antibacterial drugs protect the fish until there is an increase in antigen stimulated antibody. This procedure assures that a proportion of the test fish will survive for long term growth and survival studies even if serious epizootics of *V. anguillarum* occur.

Mortalities in Seawater

Mortalities in the seawater pens were collected daily. Those that were not decomposed were opened aseptically from the vent, and external and internal lesions were noted. Procedures described by Novotny, et al. (1975) for culturing and identifying vibriosis and other gram-negative bacteria were followed.

The mortalities were classified as follows:

a. Cause unknown.

b. Bacterial kidney disease (diagnosed from observations of gross granulomatous lesions).

c. Vibrio anguillarum: serotypes 775, 1669, or 7244.

d. Enteric red mouth disease (ERM).

e. Osmoregulatory dysfunction.

f. Furunculosis

RESULTS AND DISCUSSION

Hatchery Records

The effect of husbandry techniques, disease, and disease treatment on fish health and smolt quality is substantial. Many chemotherapeutic compounds used in the treatment of parasitic and bacterial diseases of fish can affect the smolting process (Schmidt-Nielsen 1974; Lorz and McPherson 1976), and subclinical infections may be exacerbated with the stress of seawater entry. Chemotherapeutic compounds were used on many of the test groups (Table 1) in this study during various phases of freshwater rearing. The Bonneville fall chinook salmon brought to Manchester in May 1979 had been treated with formalin and malachite green during that same month. These fish experienced a 50% mortality in the first 40 days of seawater residence, and only 12 fish survived until termination at 179 days.

Similarly, fall chinook salmon from Kalama Falls and Little White Salmon Hatcheries were treated with antibacterial drugs and disinfectants at or near the time of release. Seawater trials with fish from both hatcheries demonstrated poor survival with many fish succumbing to osmoregulatory dysfunction (Table 3). At the time of seawater entry, none of the Kalama Falls and less than 5% of the Bonneville and Little White

Table 3.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Coho											
Big Creek Group 1	200	112	56.0	88	81	7	3.5	61	30.5	20	10.0
Big Creek Group 2	200	64	32.0	136	41	95	47.5	26	13.0	15	7.5
Big Creek Group 3	200	77	38.5	123	119	4	1.3	92	30.7	27	9.0
Cascade Group 1	200	82	41.0	118	106	12	6.0	91	45.5	15	7.5
Cascade Group 2	200	104	52.0	96	95	1	0.5	75	37.5	20	10.0
Cascade Group 3	200	70	35.0	130	123	7	3.5	100	33.3	23	7.7
Toutle Group 1	200	92	46.0	108	110	2[a/]	1.0	89	44.5	21	10.5
Toutle Group 2	200	72	36.0	128	121	7	3.5	94	47.0	27	13.5
Toutle Group 3	200	68	34.0	132	126	6	3.0	107	53.5	19	9.5
Washougal Group 1	200	66	33.0	134	126	8	4.0	98	49.0	28	14.0
Washougal Group 2	200	77	38.5	123	116	7	3.5	97	48.5	19	9.5
Washougal Group 3	200	64	32.0	136	131	5	2.5	104	52.0	27	13.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD[b/]	775[c/]	1669[c/]	7244[c/]	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM[d/]	Aero Liq[e/]	Osmo Dys[f/]	Furun[g/]	Other
Coho															
Big Creek Group 1	6	0	11	1	0	0	0	0	0	2	0	0	0	0	0
Big Creek Group 2	3	1	9	2	0	0	0	0	0	0	0	0	0	0	0
Big Creek Group 3	7	0	13	6	0	0	0	0	1	0	0	0	0	0	0
Cascade Group 1	6	2	2	4	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 2	10	1	5	3	0	0	0	0	0	1	0	0	0	0	0
Cascade Group 3	10	0	11	2	0	0	0	0	0	0	0	0	0	0	0
Toutle Group 1	12	0	5	3	0	0	0	0	0	1	0	0	0	0	0
Toutle Group 2	8	1	8	6	0	0	0	1	0	3	0	0	0	0	0
Toutle Group 3	12	0	6	1	0	0	0	0	0	0	0	0	0	0	0
Washougal Group 1	13	1	7	5	0	0	0	0	0	1	0	0	0	0	1
Washougal Group 2	8	1	9	0	0	0	0	0	0	0	0	0	0	0	1
Washougal Group 3	11	0	9	7	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 3.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Baseline Coho (Toutle Stock)											
Serial Entry 1	150	47	31.3	103	103	0	0.0	88	58.7	15	10.0
Serial Entry 2	150	33	22.0	117	116	1	0.7	90	60.0	26	17.3
Serial Entry 3	151	51	33.8	100	98	2	1.3	76	50.7	22	14.7
Serial Entry 4	150	56	37.3	94	97	3 a/	2.0	77	51.3	20	13.3
Serial Entry 5	149	62	41.6	88	84	4	2.7	65	43.6	19	12.8
Serial Entry 6	150	57	38.0	93	88	5	3.3	66	44.0	22	14.7
Serial Entry 7	150	63	42.0	87	75	12	8.0	61	40.7	14	9.3
Serial Entry 8	15C	85	56.7	65	72	7 a/	4.7	54	36.0	18	12.0
Serial Entry 9	150	86	57.3	64	61	3	2.0	50	33.3	11	7.3
Serial Entry 10	150	139	92.7	11	8	3	2.0	7	4.7	1	0.7

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD b/	775 c/	1669 c/	7244 c/	775/1669	775/7244	1669/7244	1669/BKD	775/BKD	ERM d/	Aero/Liq e/	Osmo/Dys f/	Furun g/	Other
Baseline Coho (Toutle Stock)															
Serial Entry 1	10	1	3	0	1	0	0	0	0	0	0	0	0	0	0
Serial Entry 2	23	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 3	15	0	3	2	1	0	0	0	0	0	0	0	0	1	0
Serial Entry 4	12	1	5	2	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 5	7	0	9	2	0	0	0	0	0	1	0	0	0	0	0
Serial Entry 6	12	0	3	7	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 7	8	0	3	3	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 8	5	0	7	3	2	0	0	0	0	0	0	0	0	0	1
Serial Entry 9	4	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Serial Entry 10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 3.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Spring Chinook											
Carson	200	41	20.5	159	150	9	4.5	144	7.2	6	3.0
Leavenworth	200	74	37.0	126	133	7[a]	3.5	122	61.0	11	5.5

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD[b]	775[c]	1669[c]	7244[c]	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM[d]	Aero Liq[e]	Osmo Dys[f]	Furun[g]	Other
Spring Chinook															
Carson	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Leavenworth	6	0	3	1	0	0	0	0	0	1	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 3.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total recovered mortalities	Total unrecovered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Fall Chinook											
Willard Group 1	300	62	20.7	238	205	33	11.0	91	30.3	114	38.0
Willard Group 2	300	49	16.3	251	202	49	16.3	108	36.0	94	31.3
Bonneville (late yearling)	300	168	56.0	132	80	52	17.3	46	15.3	34	11.3
Spring Creek Group 1	303	67	22.1	236	200	36	11.9	83	27.4	117	38.6
Spring Creek Group 2	300	12	4.0	288	276	12	4.0	241	80.3	35	11.7
Willard Group 3	150	43	28.7	107	108	1[a]	0.7	75	50.0	33	22.0
Big White Salmon	150	11	7.3	139	130	9	6.0	116	77.3	14	9.3
Spring Creek Group 3	300	7	2.3	293	275	18	6.0	200	66.7	75	25.0
Bonneville (tules-78 brood)	300	12	4.0	288	181	107	35.7	133	44.3	48	16.0
Elokomin	300	36	12.0	264	210	54	18.0	194	64.7	16	5.3
Little White Salmon	301	37	12.3	263	237	26	8.7	148	49.3	89	29.7
Washougal	300	48	16.0	252	176	76	25.3	122	40.7	54	18.0
Toutle	133	17	12.8	116	99	17	12.8	93	69.9	6	4.5
Kalama Falls	300	41	13.7	259	238	21	7.0	87	29.0	151	50.3
Spring Creek Group 4	300	232	77.3	68	64	4	1.3	54	18.0	10	3.3

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD[b]	775[c]	1669[c]	7244[c]	775/ 1669	775/ 7244	1669/ 7244	1669/ BKD	775/ BKD	ERM[d]	Aero[e] Liq	Osmo[f] Dys	Furun[g]	Other
Fall Chinook															
Willard Group 1	3	0	0	0	1	0	0	0	0	0	0	0	110	0	0
Willard Group 2	4	1	3	1	0	0	0	0	0	1	0	0	84	0	0
Bonneville (late yearling)	3	2	1	0	0	0	0	0	0	0	0	0	28	0	0
Spring Creek Group 1	6	0	6	3	0	0	0	0	0	0	0	0	102	0	0
Spring Creek Group 2	9	0	21	4	0	1	0	0	0	0	0	0	0	0	0
Willard Group 3	0	0	0	0	0	0	0	0	0	1	0	0	32	0	0
Big White Salmon	1	0	10	2	0	0	0	0	0	0	0	0	0	0	1
Spring Creek Group 3	8	0	14	2	0	0	0	0	0	0	0	0	51	0	0
Bonneville (tules-78 brood)	4	0	7	0	0	0	0	0	0	0	0	0	37	0	0
Elokomin	3	0	6	7	0	0	0	0	0	0	0	0	0	0	0
Little White Salmon	2	0	11	4	0	0	0	0	0	0	0	0	72	0	0
Washougal	0	0	3	1	0	0	0	0	0	0	0	0	50	0	0
Toutle	1	0	4	1	0	0	0	0	0	0	0	0	0	0	0
Kalama Falls	1	0	10	1	0	0	0	0	0	0	0	0	139	0	0
Spring Creek Group 4	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Table 3.--Continued.--Inventory and seawater disease record of coho, spring, and fall chinook salmon and steelhead test groups.

INVENTORY RECORD

Test group	Fish at start of study	Fish at termination		Total loss of fish	Total re-covered mortalities	Total unre-covered mortalities		Recovered mortalities not examined (decomposed)		Recovered mortalities examined	
	(No.)	(No.)	(%)	(No.)	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Steelhead											
Chelan (Leavenworth)	200	16	8.0	184	156	28	14.0	67	33.5	89	44.5
Wells (Winthrop)	200	9	4.5	191	186	5	2.5	32	16.0	154	77.0
Tucannon	200	37	18.5	163	111	52	26.0	51	25.5	60	30.0

a/ Unaccountable gain

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES IN SEAWATER

Test group	Negative	BKD b/	775 c/	1669 c/	7244 c/	775/ 1669	775/ 7244	1669/ 7244	1699/ BKD	775/ BKD	ERM d/	Aero/ lig e/	Osmo dys f/	Furun g/	Other
Steelhead															
Chelan (Leavenworth)	3	0	20	4	4	0	3	0	0	0	0	0	55	0	0
Wells (Winthrop)	0	0	3	1	1	0	2	0	1	0	0	0	145	0	1
Tucannon	6	0	10	0	0	0	6	0	0	0	1	0	37	0	0

b/ Bacterial Kidney Disease

c/ *Vibrio anguillarum* strains 775, 1669, 7244

d/ Enteric Red Mouth

e/ *Aeromonas liquefaciens*

f/ Osmoregulatory dysfunction

g/ Furunculosis

Salmon fish were visually characterized as smolts. We cannot unequivocally relate these therapeutic treatments to subsequent failure to adapt to the seawater environment. Fish released from the hatcheries are able to migrate to ocean waters or may remain in fresh water where the status of smoltification on the presence of disease may or may not affect survival.

Health Status at the Time of Transport to Marine Environment

Table 2 summarizes the data collected from random 60 fish subsamples at the time of (or close to) hatchery release. Included are data available to date concerning the extent of latent infections of *Renibacterium salmoninarum*, the gram-positive diplobacillus that is responsible for BKD (Sanders and Fryer 1980). Mean hematocrit and hemoglobin values are also included. BKD is a chronic pathological condition affecting salmonids in fresh water and may be the cause of mortality in fish at any time during seawater residence (Novotny 1975; Ellis et al. 1978).

In 1979, the percent of BKD infections in the sampled population of yearling fall chinook salmon at the Willard Hatchery was relatively high; also, this population had infections of high intensity. The same population of fall chinook salmon sampled in the summer and fall of 1978 showed lower rates of infection; and the intensity of infection was also much lower. In this particular situation, it appears that the increased intensity of infection observed in fish held through the winter may compromise any expected benefits.

Abnormally low or high hematocrit and hemoglobin values can be due to dietary anemias, infectious disease, stage of gonad development, environmental stress, dehydration, or anoxia. Defining absolute upper and lower limits may not be realistic (Barnhart 1969). However, on the basis of past experience with the marine culture of salmonids at Manchester, hematocrit values (for any species) that fall below 30% call for a closer examination of the general health.

The normal values of hematocrit and hemoglobin (from the literature) are listed below as means or ranges:

Species	Hematocrit	Hemoglobin	Reference
Coho	32.5 to 52.5	6.5 to 9.9	Wedemeyer & Chatterton (1971)
Fall chinook	35 to 39	-	Oregon Fish & Wildlife Service (OFWS) (Unpublished Report)
Spring chinook	35	11.5	OFWS

Examination of the test groups in Table 2 shows that few of the mean values for hematocrit or hemoglobin were above or below values considered normal, with one exception--the yearling fall chinook salmon from Willard Hatchery. This was the most anemic population of fish encountered thus far, with a mean hematocrit value of 26.5% and a hemoglobin value of 3.2 mg/dcl of blood. This condition also coincides with a 56.7% BKD infection rate, which is probably the cause of the anemia.

Mortality after Transfer to Seawater Net-Pens

Table 3 is a summary of survival data and the principal causes of mortalities for the groups tested in seawater net-pens at Manchester.

The majority of the fall chinook salmon and steelhead mortalities were due to osmoregulatory dysfunction or vibriosis contracted in the marine environment. Enteric redmouth disease (ERM) was identified from only one fish during the entire 1979 seawater trials, a Tucannon steelhead. There was no record of ERM during the freshwater rearing of the Tucannon steelhead. However, fall chinook salmon from five releases at Spring Creek and Big White Salmon Hatcheries had histories of ERM. It is conceivable that Yersinia ruckerii, the etiological agent of ERM, could be transmitted horizontally in the marine environment.

During the 1979 seawater trials only one fish succumbed to furunculosis, a Montlake coho baseline salmon. These fish were infected with furunculosis during the freshwater rearing and the only other furunculosis documented from the hatcheries was from the Toutle Hatchery.

It is impossible to ignore the obvious disparity between detected levels of latent BKD and the relative absence of frank kidney disease after 5-6 months of seawater residence. The presence of other bacilli in the kidneys is recognized, and the possibility of cross-reactive components allowing false positive readings for BKD is the basis for the rigid control methods used with the IFAT. Our control slides were constantly tested and we are confident of our findings. A more realistic explanation of the lack of gross BKD in seawater might be derived from an examination of the nature of the causitive organism R. salmoninarum and the response of the infected fish. Renibacterium salmoninarum produces a slowly developing chronic infection which could allow the host to adapt to or tolerate its presence, particularly in the absence of other stress.

Mortality in seawater attributed to unknown causes was comparatively high, particularly in coho salmon. Attempts to diagnose the cause of mortality were limited to the more commonly encountered diseases listed in Table 3. The possible effects of other pathogenic organisms heretofore unrecognized in marine salmon culture cannot be ignored. Recently a previously undescribed protozoan parasite has caused substantial mortality in coho salmon at a private farm near the Manchester research facility.

An addendum to the 1978 PNRC Report, Table 4, shows the completed BKD assays for that year. It is interesting to note that in 1978 all but two stocks of fish, the Leavenworth and Kalama Falls spring chinook salmon, were infected with BKD and no hatchery stocks examined in 1979 were free of this disease.

ADDENDUM

Table 4.--Covert BKD infections in 1978 hatchery trials.

		% BKD infection
Willard I	Coho	15.0
Willard II	"	16.7
Willard III	"	40.7
Kalama	"	85.0
Big Creek/Cowlitz	"	31.6
Big Creek/Big Creek	"	6.7
Carson	"	5.0
Sandy	"	30.0
Klickitat	"	3.3
Toutle	"	46.7
Bonneville I	Fall Chinook	10.1
Bonneville II	"	5.0
Willard I	"	41.7
Willard II	"	36.6
Spring Creek	"	0
Cowlitz	"	93.3
Little White Salmon	"	11.6
Kalama I	"	11.6
Kalama II	"	3.3
Toutle	"	6.7
Kooskia	Spring Chinook	90.0
Leavenworth	"	0
Kalama	"	0
Carson	"	50.8
Chelan	Steelhead	86.7
Tucannon	"	21.7
Wells	"	83.3
Dworshak	"	16.7
Skamania	"	63.3

LITERATURE CITED

Barnhart, R. A.
1969. Effects of certain variable hematological characteristics of rainbow trout. Trans. Amer. Fish. Soc. 98(3), p 411-18.

Bullock, G. L., and H. M. Stuckey.
1975. Fluorescent antibody identification and detection of the Corynebacterium causing kidney disease of salmonids. J. Fish. Res. Bd. Can. 32(11) p 2224-2227.

Ellis, Richard, A. J. Novotny, and Lee W. Harrell.
1978. Case report of kidney disease in a wild chinook salmon, Oncorhynchus tshawytscha in the sea. J. Wildlife Dis. 14 p 120-123.

Lorz, H. W., and B. P. McPherson.
1976. Effects of copper or zinc in freshwater on the adaptation to seawater and ATPase activity and the effects of copper on migratory disposition of coho salmon Oncorhynchus kisutch. J. Fish. Res. Bd. Can. 33(9), p 2023.

Novotny, A. J.
1975. Net-pen culture of Pacific salmon in marine waters. Mar. Fish. Rev. 37(1), p 36-47.

Novotny, A. J., L. W. Harrell, and C. Nyegaard.
1975. Vibriosis: A common disease of Pacific salmon cultured in marine waters of Washington. Wash. State Univ. Ext. Bull. 663, p 1-8.

Ossiander, F. J., and G. Wedemeyer.
1973. Computer program for sample sizes required to determine disease incidence in fish populations. J. Fish. Res. Bd. Can. 30, p 1383-4.

Sanders, J. E., and J. L. Fryer.
1980. Renibacterium salmoninarum Gen. Nov., Sp. Nov., the causative agent of bacterial kidney disease in salmonid fishes. Int. J. of Syst. Bact. 30(2)p.496-502.

Schmidt-Nielsen, B.
1974. Osmoregulation: Effect of salinity and heavy metals. Fed. Proc. 33(10), p 2137.

Wedemeyer, G., and K. Chatterton.
1971. Some blood chemistry values for the juvenile coho salmon (Oncorhynchus kisutch). J. Fish. Res. Bd. Can. 28, p 606-8.

APPENDIX E

FRESHWATER GROWTH AND SMOLTING CHARACTERISTICS OF TOUTLE RIVER COHO SALMON REARED FOR BASELINE DATA COMPARISON

by

James L. Mighell

September 1980

APPENDIX E

INTRODUCTION

Juvenile coho salmon (Oncorhynchus kisutch) normally spend a full year in fresh water before migrating to the marine environment. Near the time of migration they experience physiological changes that adapt them to seawater. The timing of these changes and the relative strength of associated biochemical and morphological characteristics appears to be variable due to genetic and environmental variations.

The objective of this study was to rear a single stock of coho salmon of two age-classes, sub-yearling and yearling smolts, under known environmental conditions in fresh water to obtain baseline physiological and seawater adaptation data for comparison with other stocks. The stock chosen for this study was the Toutle River coho salmon. This stock originated in the Green River, a tributary of the Toutle River.

METHODS AND MATERIALS

Eyed eggs of the Toutle River coho salmon stock were obtained at the Toutle River Hatchery (Washington Department of Fisheries) in November 1977 and incubated and reared at the Northwest and Alaska Fisheries Center in Seattle, Washington. The fish were reared under two different temperature regimes to obtain sub-yearling (0-age) and normal yearling smolts. This report covers data pertaining to normal yearling smolts in fresh water. Data on sub-yearling smolts raised at elevated temperatures were discussed in the FY 1978-79 report.

Eggs and alevins were incubated in Heath type incubators. The fingerlings were reared in dechlorinated municipal water in 4-foot diameter circular fiberglass tanks located outdoors under natural lighting. Oxygen levels in the water were monitored weekly and maintained at or near saturation at all times by adjusting water flow. The pH was 6.4 to 7.2, and total $CaCo_3$ alkalinity was 12 ppm (± 4 ppm). Ammonia nitrogen levels from fish excretions were less than 1.0 ppm, corresponding to 3.0 ppb or less un-ionized ammonia. Rearing temperatures ranged from 4° to 20°C (Figure 1).

Initially each rearing tank held 2,200 fish--rearing density did not exceed 73 g/liter during the study. The population was sampled every 3 weeks to determine growth and status of smoltification. Smolt status was determined by morphological and biochemical criteria (Appendix F). Morphological characteristics of specific smolting phases were as follows:

1. Parr--light brown to yellowish overall color, yellow to brownish-orange fin color, parr marks very evident.

2. Transitional--parr marks fading, partly silvery body, fin color becoming clear or uniform light gray.

3. Smolt--parr marks nearly or completely obscured by the extremely silvery body, dorsal and caudal fins clear with dark black fringe, and a general slimming of the body.

Disease therapy was required. Epizootics of furunculosis and myxobacterial diseases were treated with 2% Terramycin and 0.3% chloramphenicol in the diet for 10-day periods.

Starting 15 March 1979, 400 to 600 fish were randomly selected and transported to Manchester, Washington for seawater adaptability testing. (See Appendix F). A total of ten such groups were introduced to seawater biweekly until June 1979 and at monthly intervals thereafter until 14 September 1979. Physiological parameters such as gill sodium-potassium

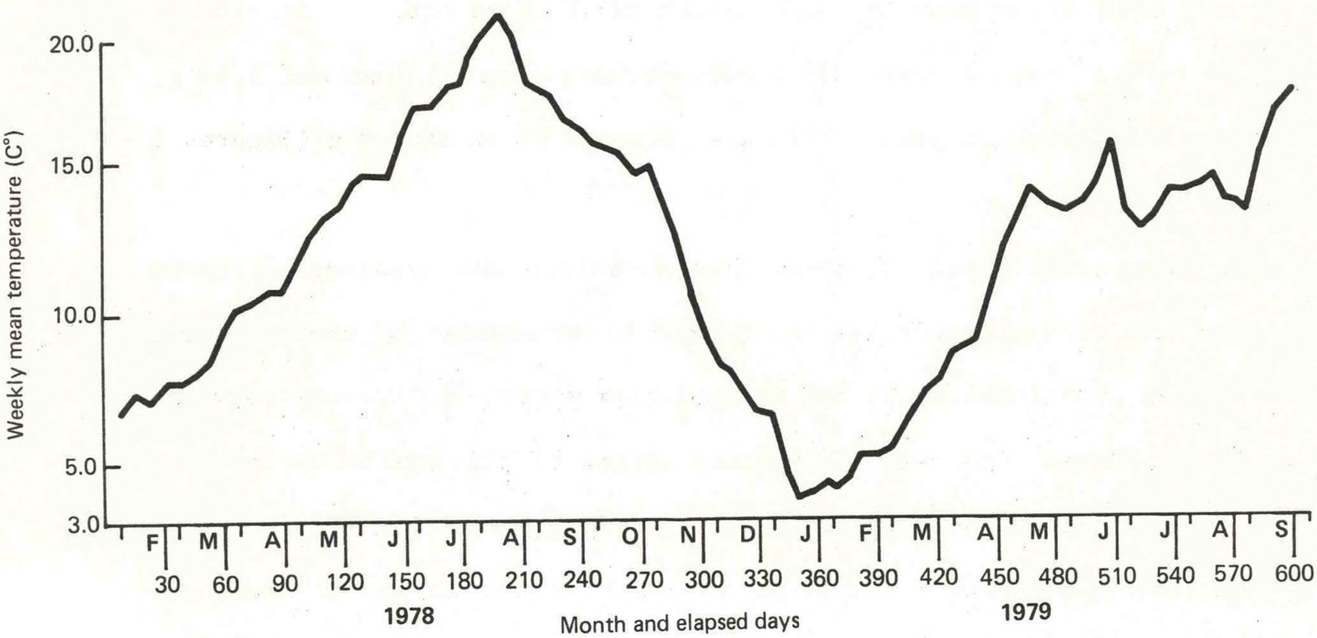


Figure 1.--Freshwater rearing temperatures for Toutle River coho salmon reared for baseline smolt transformation comparison. Jan. 1978-Sep. 1979.

adenosinetriphosphatase (gill Na^+-K^+ ATPase); plasma thyroxine (T_4) and triiodothyronine (T_3); and the plasma electrolytes sodium (Na^+), potassium (K^+), chloride (Cl^-), calcium (Ca^{++}) and magnesium (Mg^{++}) were determined on random biweekly samples. The samples were taken before and after entry into seawater to determine possible relationships to smolting. (Appendix F).

RESULTS AND DISCUSSION

The swim-up fry reared under a normal temperature regime began feeding 27 January 1978 at an average fork length of 35.3 mm and an average weight of 0.36 g. By 10 June 1978 these averages were 63.8 mm and 3.43 g, and by the third week of August 1978 they reached 85 mm and 10 g (Figures 2 and 3).

The first indication of smolt transformation was apparent 14 March 1979 when 7.7% of the population was judged to be smolted by morphological criteria. An additional 62.5% had changed from parr to a "silvery parr" or transitional phase. The mean length and weight of the population at that time had increased to 135.2 mm and 31.3 g, respectively.

The fish continued to grow to a length of 155 mm and a weight of 42.4 g by mid-May (serial seawater entry group five), the peak of smolting. At that time 80% of the population remaining in fresh water was fully smolted with the others in the transitional phase; no parrs were evident. Near the end of June, smolt characteristics of the fish in fresh water began to fade noticeably; and by the third week of July, only 39.4% were judged to be smolts, and 6% of the fish were fully reverted to a parr-like condition. At the end of the experimental holding period in late September 1979, the fish in fresh water averaged 195 mm in length and 104.3 g in weight, and 24.7% had reverted to parr.

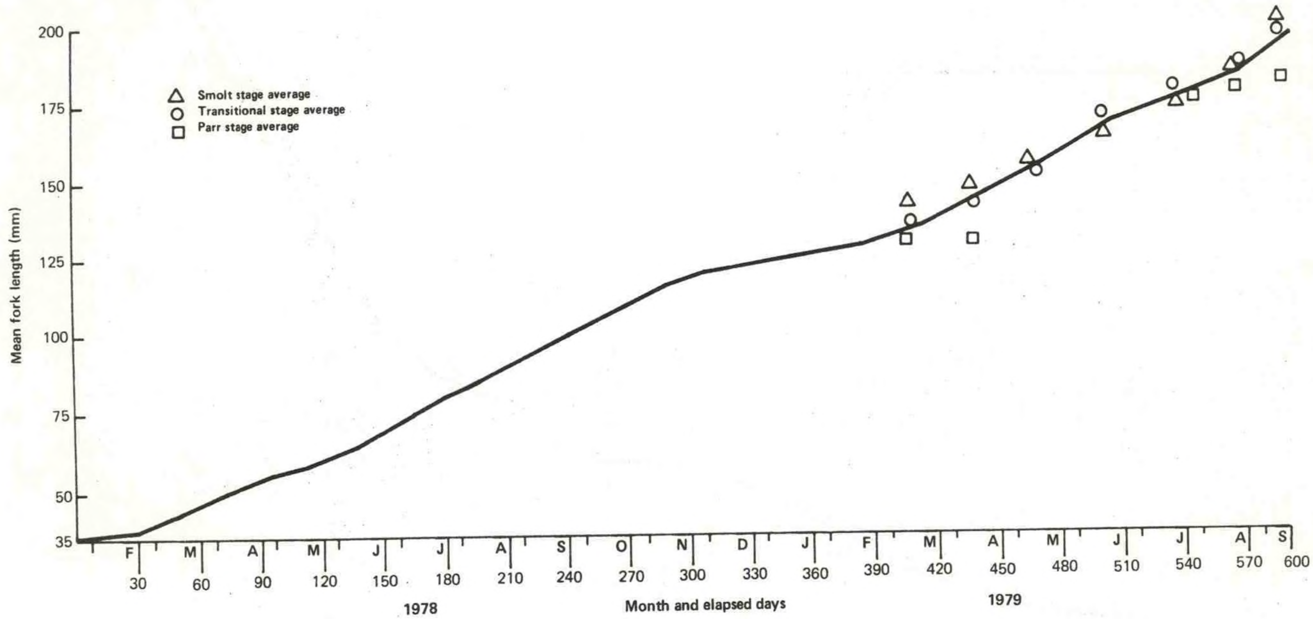


Figure 2.--Freshwater growth of Toutle River coho salmon reared for smolt transformation comparison. Jan. 1978-Sep. 1979. Mean fork lengths of smolt, transitional, and parr are indicated.

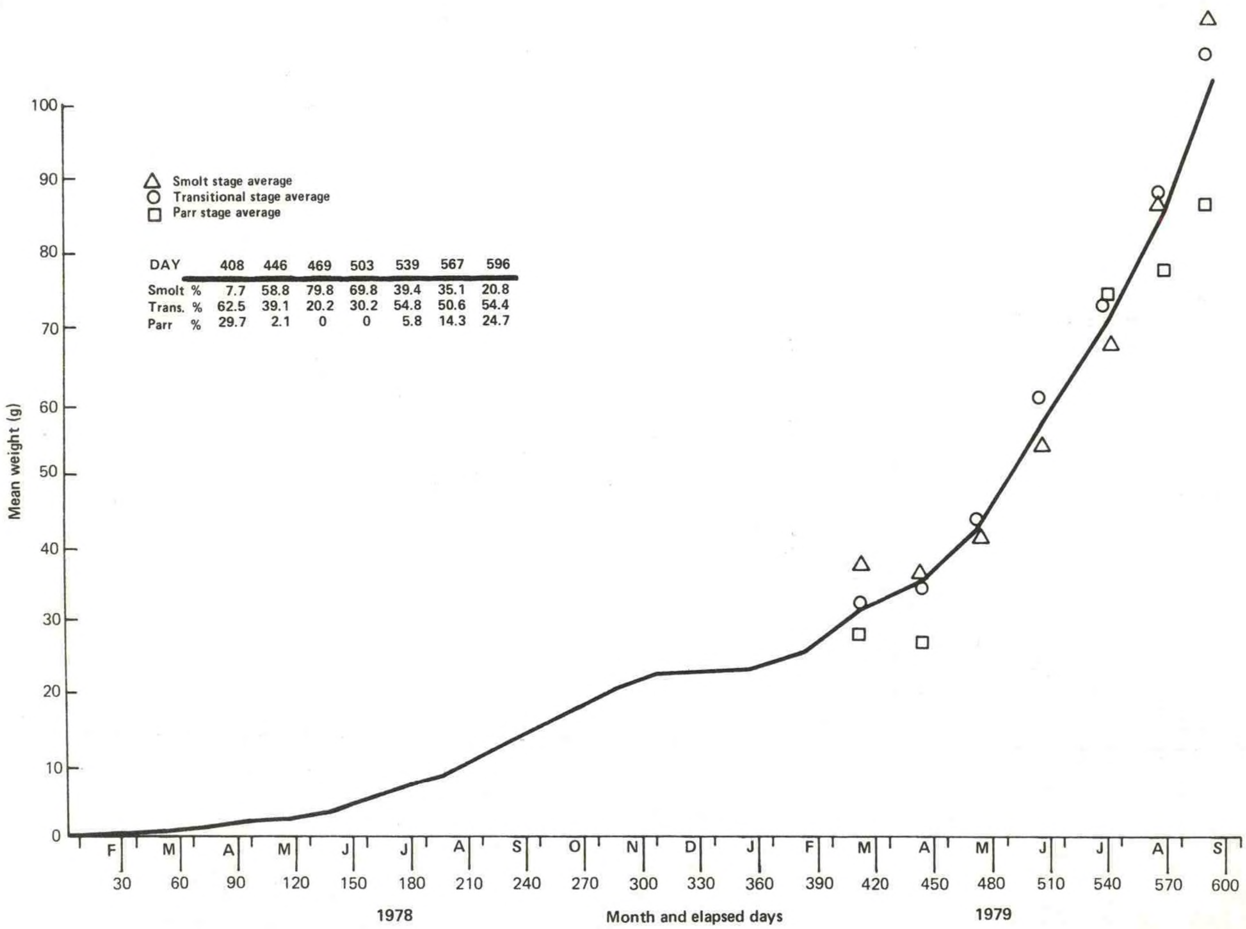


Figure 3.--Weight of Toutle River coho salmon reared for smolt transformation comparison. Jan. 1978-Sep. 1979. Percentage of the population in each phase of smolt transformation is shown in inset table.

The condition of the fish (K) (Carlander 1953) varied throughout the rearing period (Figure 4). Swim-up fry had low K values (K = 0.805). As the temperature increased (Figure 1) and the fish grew, the K value increased (K = 1.250 to 1.340) and the fish appeared full-bodied. In October 1978, as temperature decreased and feeding activity declined, the K value decreased to a low in mid-January (K = 1.114). As temperature increased through mid-March 1979, the condition index increased until the onset of the parr-smolt transformation, when the K values decreased despite excellent weight gains (Figure 3). As the smolting period passed in early July, the K value again increased to the mid-March level of K = 1.250 where it remained until the end of the study.

Weekly mortalities are presented in Figure 5. After 210 days of freshwater rearing the total mortality was only 0.95%. However, by the 238th day an additional 8.4% loss was caused by myxobacterial gill disease. This outbreak of disease subsided after treatment with oxytetracycline antibiotic (Terramycin). However, just 21 days later, an epizootic furunculosis (Aeromonas salmonicida) disease caused a loss of 3.9%. No drug treatments were administered and the disease subsided spontaneously. A water failure during January 1979 caused a 6.2% loss. These were the only significant mortalities until the second week of May, when a reoccurrence of furunculosis caused an additional 7.5% loss by the third week of June 1979. The latter epizootic was treated repeatedly with chloramphenicol for 10-day periods beginning on 15 May, 11 June, and 21 June. No losses occurred from 25 June (day 511) to 24 July (day 541) and only minor losses thereafter to the end of the study. No antibiotic treatments were administered after 30 June.

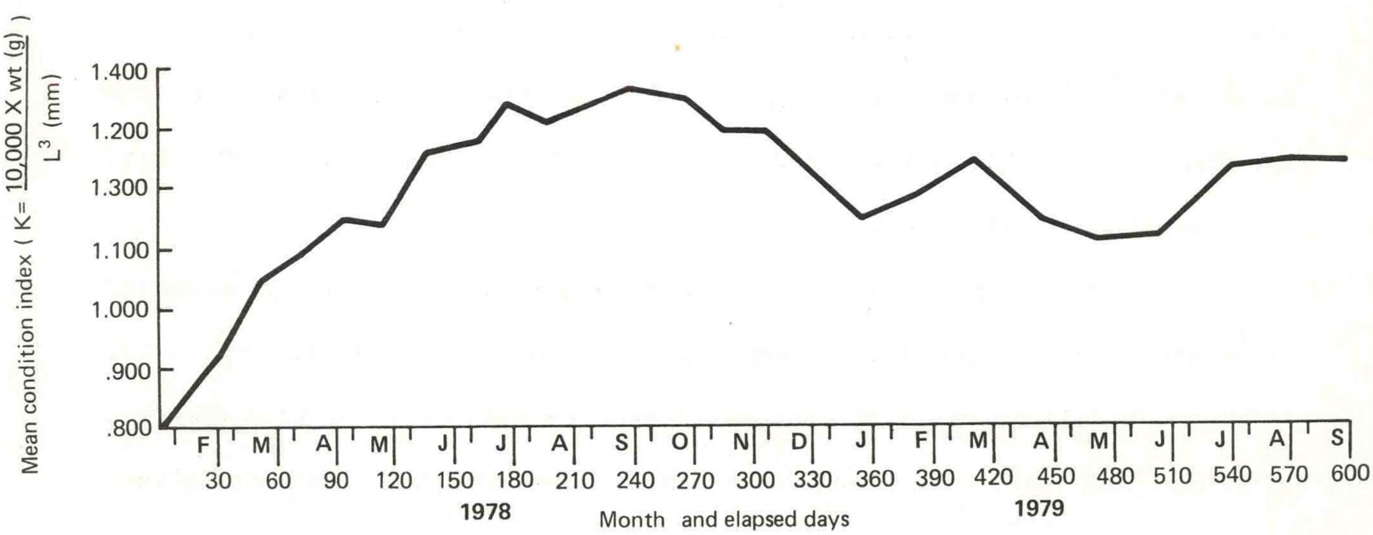


Figure 4.--Condition Index values (K=Wt x $10000/L^3$) during freshwater rearing of Toutle River coho salmon, Jan. 1978-Sep. 1979.

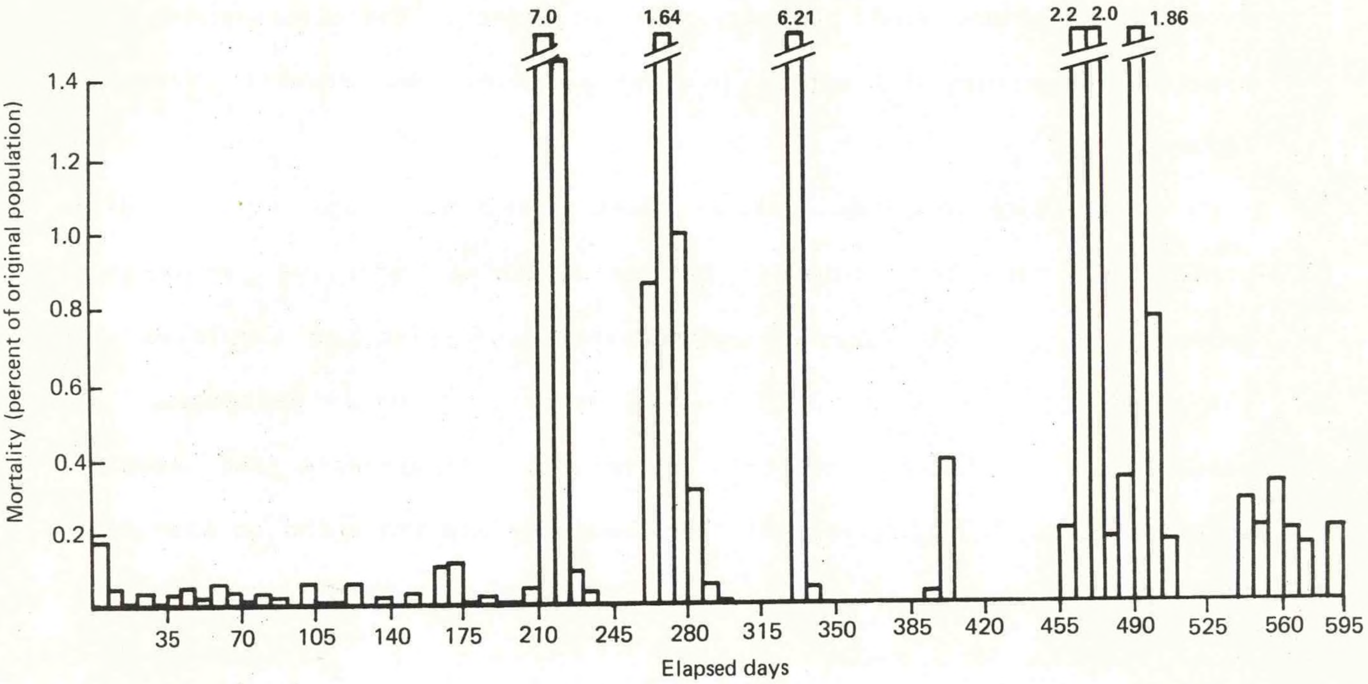


Figure 5.--Weekly mortalities of Toutle River coho salmon, Jan. 1978-Sep. 1979.

The occurrence of furunculosis disease during the peak period of smolting appeared to have little effect on the ability of the fish to smolt as determined by morphological characteristics. Likewise, there was no apparent indication that treatments with chloramphenicol antibiotic, known to alter mammalian blood chemistry, had any effect. The diseases and their treatment, however, did appear to have an effect on seawater adaptation (Appendix B).

The culture of coho salmon under accelerated and ambient water conditions for the purpose of establishing baseline biochemical measurements of smoltification and seawater adaptation was completed with the seawater entry of the tenth serial entry group on 14 September. The results and discussion of the biochemical measurements and seawater adaption tests in both fresh water and seawater are presented in Appendixes B and F.

LITERATURE CITED

Carlander, Kenneth D.
1953. Handbook of Freshwater Fishery Biology. 429 p. Wm. C. Brown Company, Dubuque, Iowa.

APPENDIX F

A Comparison of Physiological Changes Associated with Smoltification and Seawater Adaptation in Three Species of Anadromous Salmonids

by

Leroy C. Folmar
Waldo S. Zaugg
Robert E. King
James L. Mighell
and
Walton W. Dickhoff

September 1980

INTRODUCTION

In our previous report (Folmar et al. 1979), we evaluated some physiological changes associated with smoltification in yearling coho salmon, Oncorhynchus kisutch, from Columbia River hatcheries. We also measured the same parameters in 0-age coho salmon reared on an accelerated growth regime at the National Marine Fisheries Service Montlake laboratory.

The current study evaluates the physiological changes observed in the yearling cohorts of last year's 0-age study and compares the physiological changes associated with smoltification in yearling coho and chinook salmon (O. tshawytscha) and steelhead (Salmo gairdneri) from several state and federal hatcheries (Table 1). In addition to the measurements made last year [gill Na^{+}-K^{+} ATPase, plasma thyroxine (T_4), triiodothyronine (T_3), and sodium (Na^{+}), potassium (K^{+}), and chloride (Cl^{-}) ions], we measured plasma calcium (Ca^{++}), and magnesium (Mg^{++}) ions. The relationships of the parameters studied to smolt quality and their possible role in the early development of anadromous salmonids are discussed.

METHODS AND MATERIALS

Yearling coho and spring chinook salmon and steelhead in this study were obtained from hatcheries on tributaries to the Columbia River. The hatcheries included: Chelan, Tucannon, Leavenworth, Carson, Toutle, and Big Creek. Biochemical profiles of fish in fresh water were established on each test group prior to release from their respective hatcheries. Sampling at the hatcheries commenced in March and continued at approximately 2-week intervals through July. Serial release programs for yearling coho salmon at the Big Creek and Toutle hatcheries enabled us to

Table 1.--Test groups evaluated biochemical during seawater rearing.

Species	Experimental test group	Entry group	Seawater entry date	Mean weight (g) at seawater entry	Number at fish seawater entry	Termination date	Mean weight (g) at termination	Number fish at termination	Percent smolted fish in test group at termination (a)	Percent survival of test group at termination (b)	Percent surviving smolts in test group at termination (axb)
Coho-0-age	1978 baseline	1	17 May	5.4	150	01 November	35.1	24	12	16	2
	"	2	01 June	6.7	150	01 November	34.4	20	15	13	2
	"	3	15 June	8.0	150	01 November	41.2	28	32	19	6
	"	4	28 June	9.6	150	01 November	39.0	44	36	29	11
	"	5	12 July	11.7	150	01 November	36.2	63	33	42	14
	"	6	26 July	12.9	150	01 November	36.1	53	28	35	10
	"	7	09 August	15.2	150	01 November	33.5	21	33	14	5
	"	8	23 August	15.5	150	01 November	19.8	18	6	12	1
Coho-yearlings	1979 baseline	1	19 March	29.7	150	05 November	101.5	47	87	31	27
	"	2	02 April	30.7	150	05 November	100.8	33	73	22	16
	"	3	16 April	34.8	150	05 November	145.7	51	84	34	29
	"	4	30 April	38.2	150	05 November	98.0	56	90	37	33
	"	5	14 May	41.8	149	13 November	109.1	62	91	41	37
	"	6	29 May	44.6	150	13 November	102.6	57	84	38	32
	"	7	11 June	50.7	150	13 November	101.3	63	89	42	37
	"	8	23 July	68.8	150	13 November	108.4	85	85	57	48
	"	9	20 August	81.0	150	13 November	108.5	86	84	57	48
Coho-	Toutle	1	08 May	24.0	200	14 November	85.9	92	70	46	32
	"	2	06 June	21.9	200	11 November	82.4	72	83	36	30
	"	3	09 July	24.2	200	14 November	60.8	68	50	34	17
	Big Creek	1	08 May	23.5	200	14 November	82.3	112	82	56	46
	" "	2	08 June	23.4	200	14 November	88.4	64	77	32	25
	" "	3	07 July	23.8	200	14 November	62.6	77	55	38	21
Spring chinook	Leavenworth	1	26 April	25.4	200	20 November	180.4	74	100	36	36
	Carson	1	02 May	23.0	200	20 November	131.9	41	100	21	21
Steelhead	Chelan	1	26 April	113.5	200	20 November	191.8	16	56	8	5
	Tucannon	1	15 May	41.3	200	19 November	155.0	37	46	19	8

evaluate the effects of three seawater entries (May, June, and July) on survival and smoltification. Fish held for the June and July releases were maintained on reduced rations in an attempt to have fish of equal size at each release.

The Montlake-Toutle baseline study (Appendix E) was designed to provide a comparison of developmental and seawater adaptation patterns in 0-age coho salmon on an accelerated growth regime and normal yearling coho salmon from the same lot of eggs. The procedures for rearing 0-age fish have been previously described (Mighell 1979), while those for yearling fish are reported in this document.

The seawater acclimation portion of the Montlake-Toutle baseline study consisted of 10 serial seawater entry periods for both 0-age fish (May-August, 1978) and yearling fish (March-August 1979). The 0-age fish were transferred biweekly while the yearling coho were transferred to seawater biweekly until June, 1979, then at monthly intervals thereafter (Table 1). Upon entering seawater, blood and tissue samples were generally taken on days 1 through 8 of seawater residence for 0-age fish and 1 through 3 for yearling fish. Additional samples were taken after 30 days and at termination of seawater holding for 0-age fish and at 10 days and termination for yearlings.

Samples for biochemical analysis were not collected on entry periods 7 or 10 in yearling fish and were collected only for the last 2 and 3 days of the 8- day seawater biochemical evaluation period of entries 8 and 7, respectively, of the 0-age fish. Separate groups of fish from all entry periods were maintained in seawater net-pens for the purpose of assessing survival, growth, latent disease, and status of smoltification over time.

RESULTS AND DISCUSSION

Baseline Study

Observation of changes in gill Na^+-K^+ ATPase during smoltification and the interrelationships of Na^+-K^+ ATPase with the other measured physiological parameters in yearling coho salmon were similar to those previously described for other yearling coho salmon (Folmar et al. 1979). However, we observed essentially no change in enzyme activity during the same experimental period in the 0-age fish (Figure 1). Also, in 0-age fish there were no statistically significant relationships between gill Na^+-K^+ ATPase activity and plasma concentrations of T_4 or T_3. Despite large differences in Na^+-K^+ ATPase activity between the two age groups in fresh water, both groups had seawater acclimation patterns (Figures 2 and 3) similar to those previously described for coho salmon (Folmar and Dickhoff 1979, 1980; Folmar et al. 1979). As in our previous report (Folmar et al 1979), we found no statistically significant relationships between any freshwater Na^+-K^+ ATPase enzyme measurements in either yearling or 0-age fish and their success in seawater as measured by percent survival or percent smolts at the termination of seawater holding (Table 1).

Although our measurements of gill Na^+-K^+ ATPase in growth accelerated 0-age Toutle coho salmon showed little change during the period of smoltification, other 0-age stocks have shown elevated gill Na^+-K^+ ATPase activities more similar to yearling fish (Zaugg, unpublished observations). It should be noted that the size of the 0-age fish which were evaluated in this study were smaller than normal yearling and 0-age fish at the time of seawater entry (Table 1). This factor could account for the differences in the observed Na^+-K^+ ATPase activity patterns.

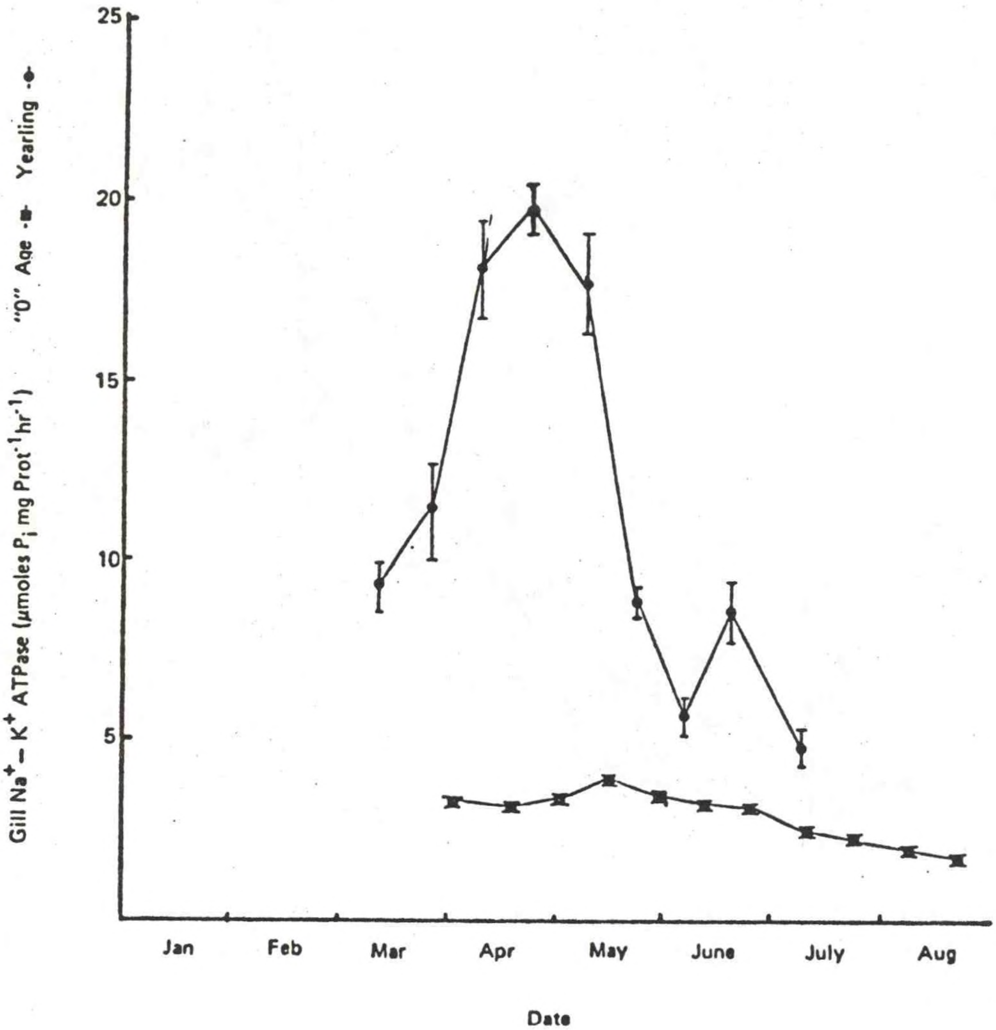


Figure 1.--Gill Na^{+}-K^{+} ATPase activities vs time for 0-age and yearling baseline coho salmon during smoltification in fresh water.

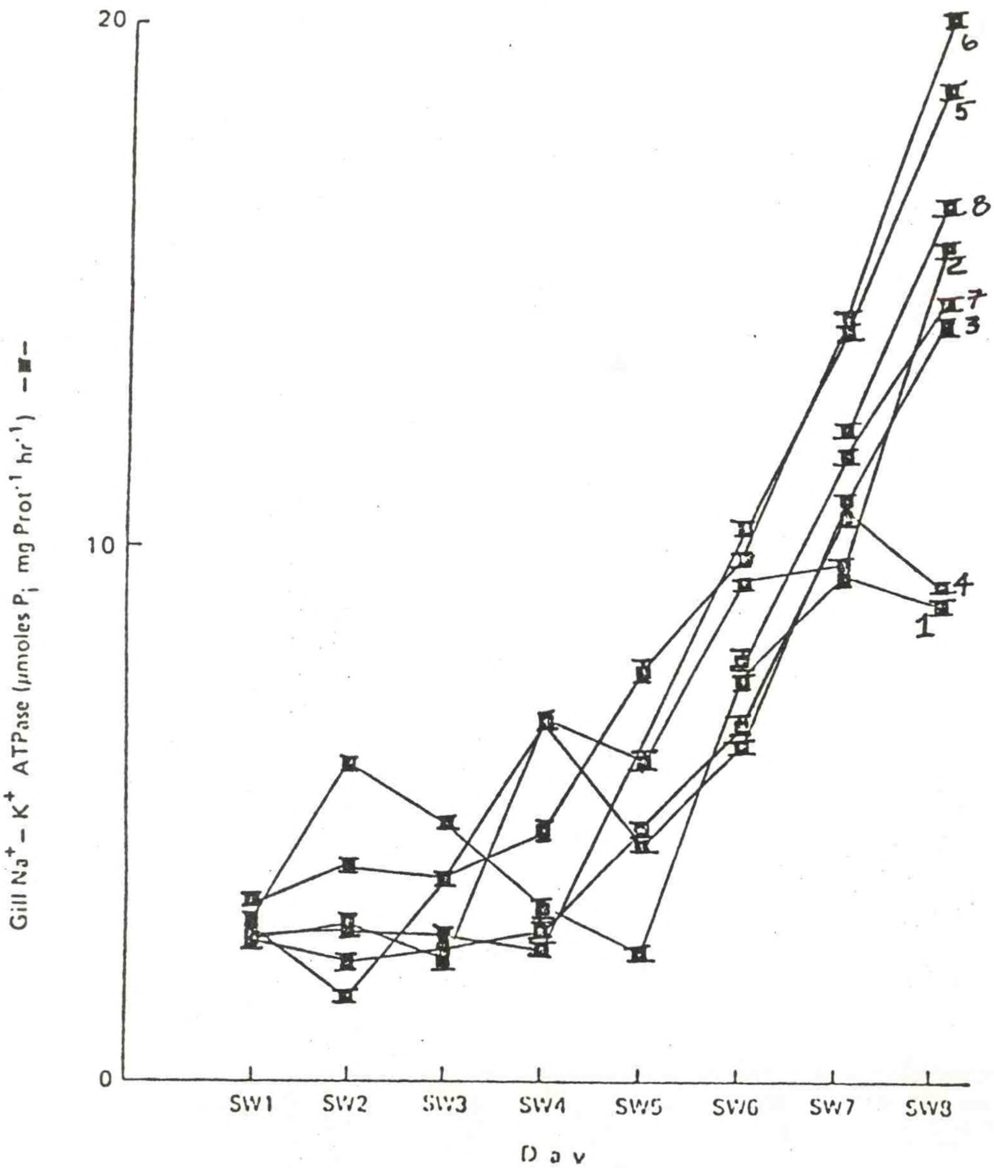


Figure 2.--Gill Na^{+}-K^{+} ATPase activities vs time for eight groups of 0-age baseline coho salmon during their initial period of seawater, acclimation. Groups of fish (1 through 8) were sequentially transferred to seawater (Table 1).

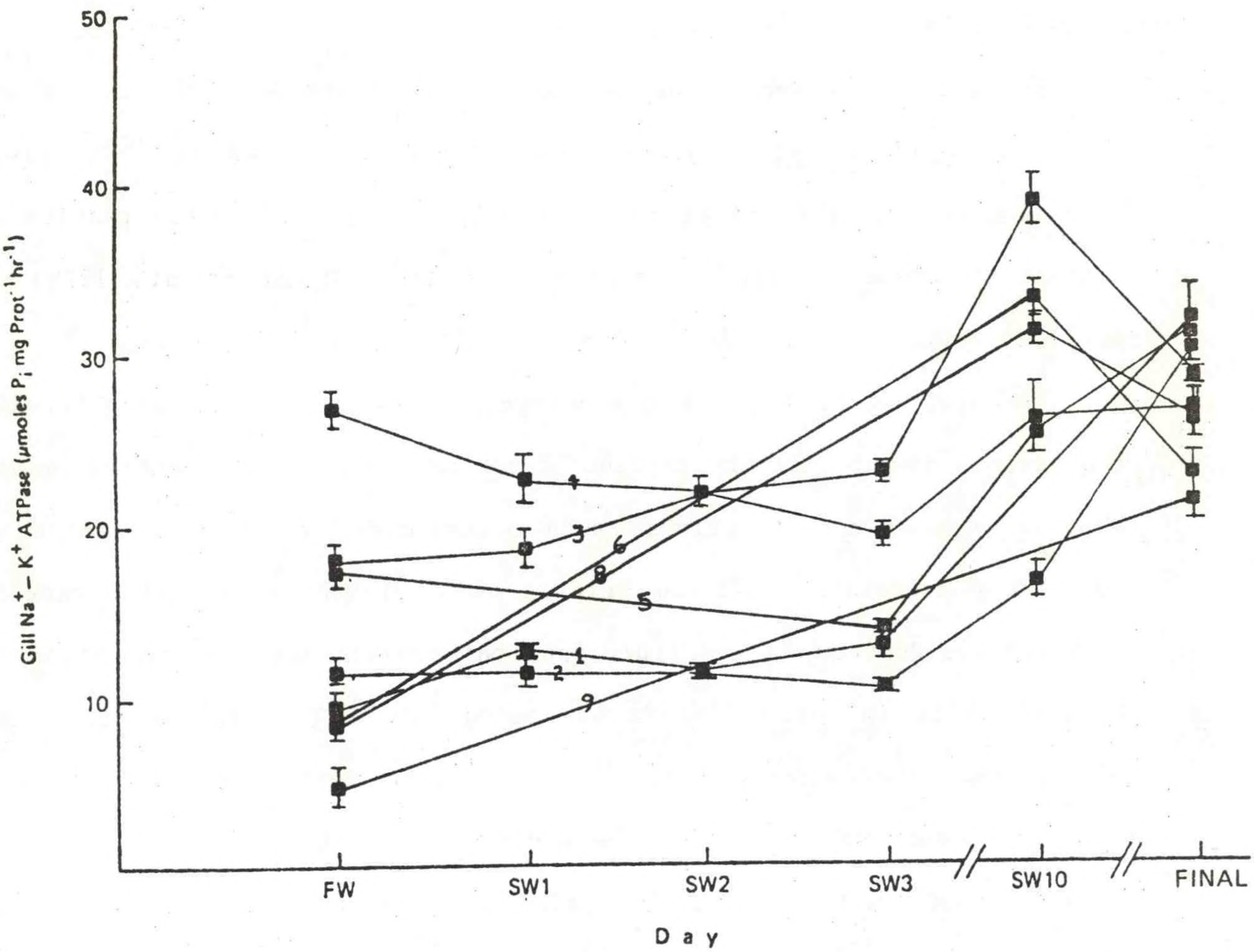


Figure 3.--Gill Na^+-K^+ ATPase activities vs time for eight groups of yearling baseline coho salmon during seawater acclimation. Groups of fish (1 through 6, 8 and 9) were sequentially transferred to seawater (Table 1).

Observed springtime plasma T_4 peaks for both 0-age and yearling coho salmon (Figure 4) were probably a result of neuroendocrine activation of the thyroid in response to changes in photoperiod and temperature (Folmar and Dickhoff 1980). Although plasma T_4 elevations were observed in both 0-age and yearling fish, the magnitude of increase was greater in the yearling fish.

Patterns of change in plasma T_3 concentrations were similar in both 0-age and yearling fish (Figure 5). Plasma T_3 peaks were of lesser magnitude and occurred later than the plasma T_4 peaks. These results are similar to those previously reported for coho (Folmar et al. 1979) and masou (Nishikawa et al. 1979) salmon.

The analyses of thyroid hormone cycles of 0-age and yearling baseline coho salmon showed that the percent of the area beneath the peaks of plasma thyroid hormone concentrations which occurred before seawater entry was positively correlated with the percent of surviving smolts after extended seawater residence. In yearling fish, this relationship was based on the T_4 peak while in 0-age fish it was based on the T_3 peak (Figures 6 and 7). These correlations suggest that yearling fish will have a better chance for survival in the marine environment if they are transferred to seawater near the end of the T_4 cycle in fresh water. In contrast, data presented here suggest that 0-age fish should show greater survival if they are transferred to seawater near the end of the T_3 cycle occurring later in the summer. Thus, analysis of the changes in plasma T_4 and T_3 concentrations during freshwater residence appear to be potentially useful predictive indices of seawater survival of 0-age and yearling coho salmon, respectively. These results confirm our previous findings with yearling

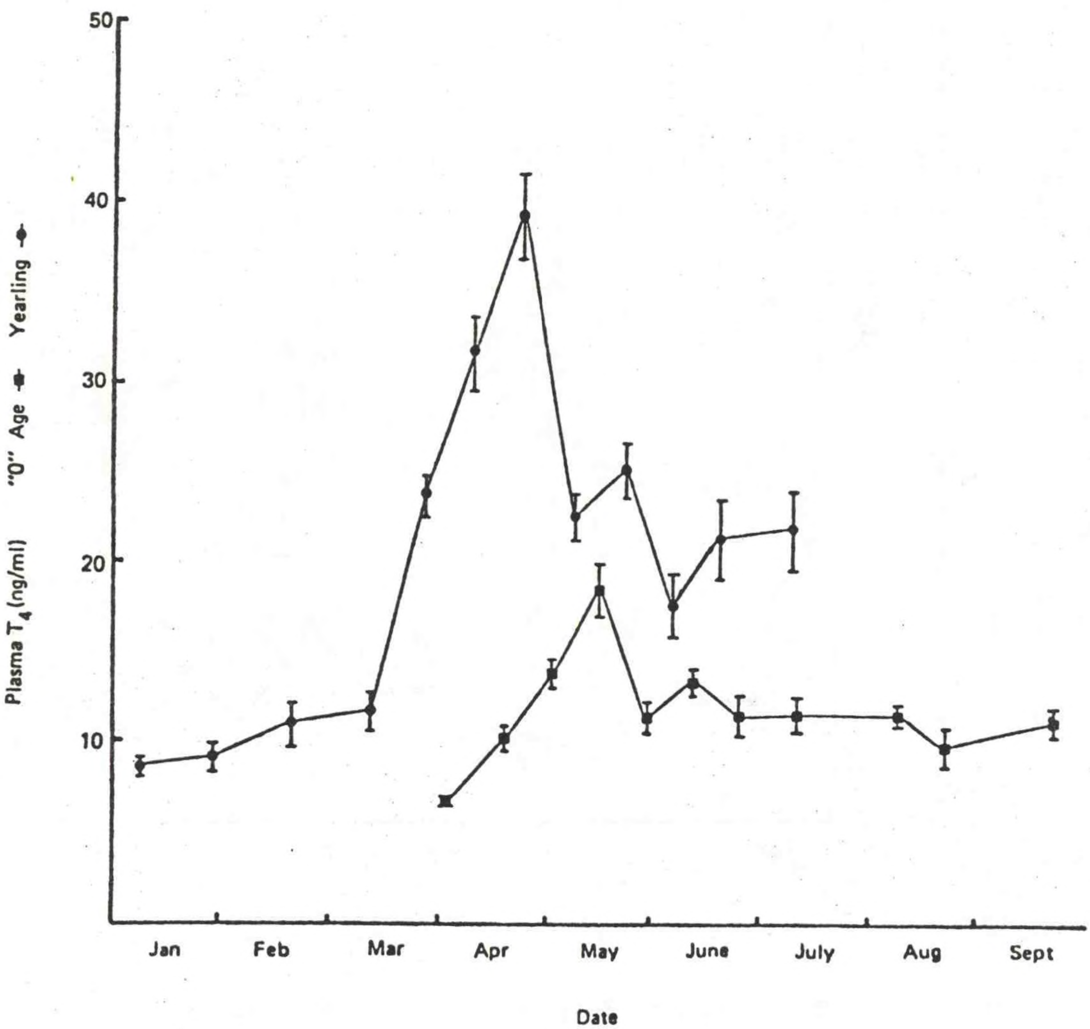


Figure 4.--Plasma T_4 concentrations vs time for 0-age and yearling baseline coho salmon during smoltification in fresh water.

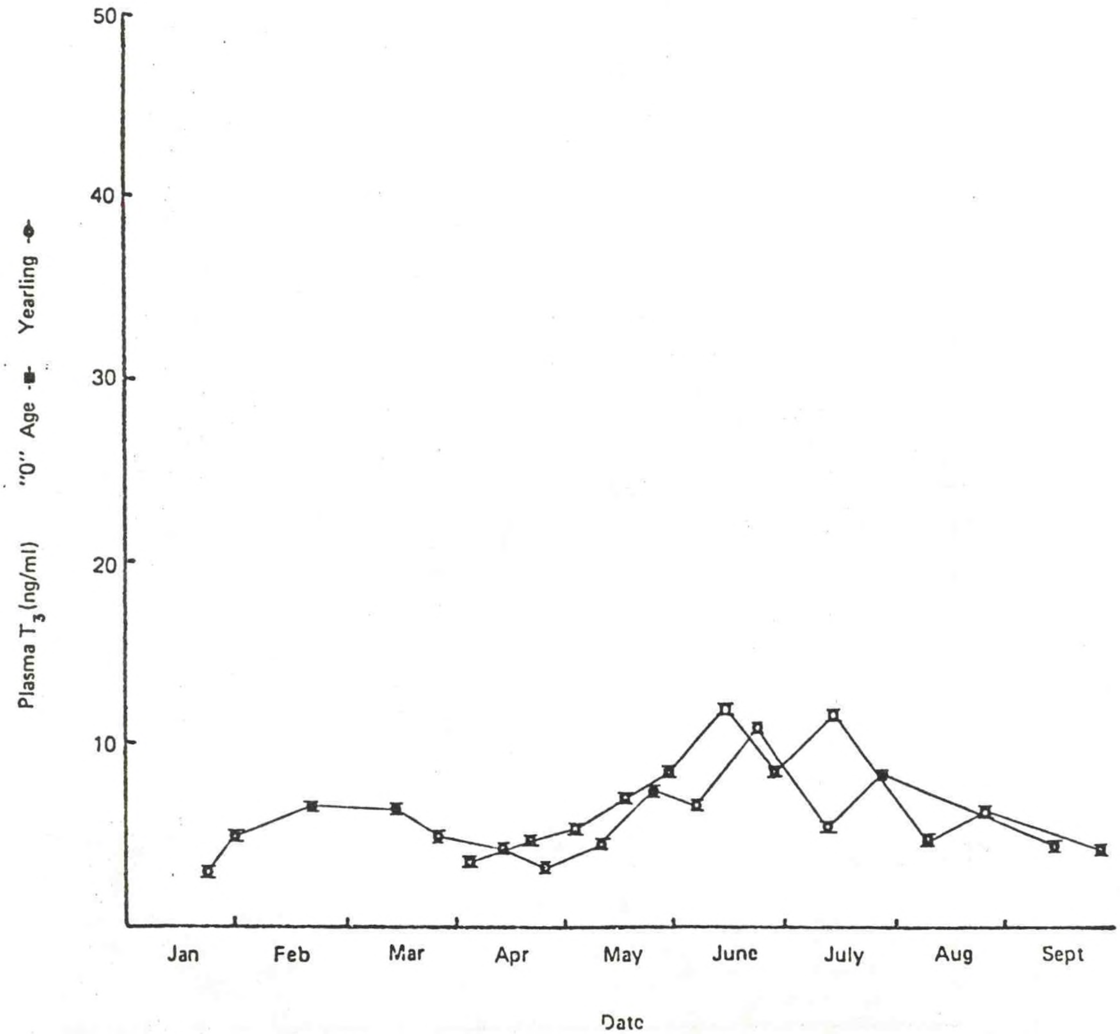


Figure 5.--Plasma T_3 concentrations vs time for 0-age and yearling baseline coho salmon during smoltification in fresh water.

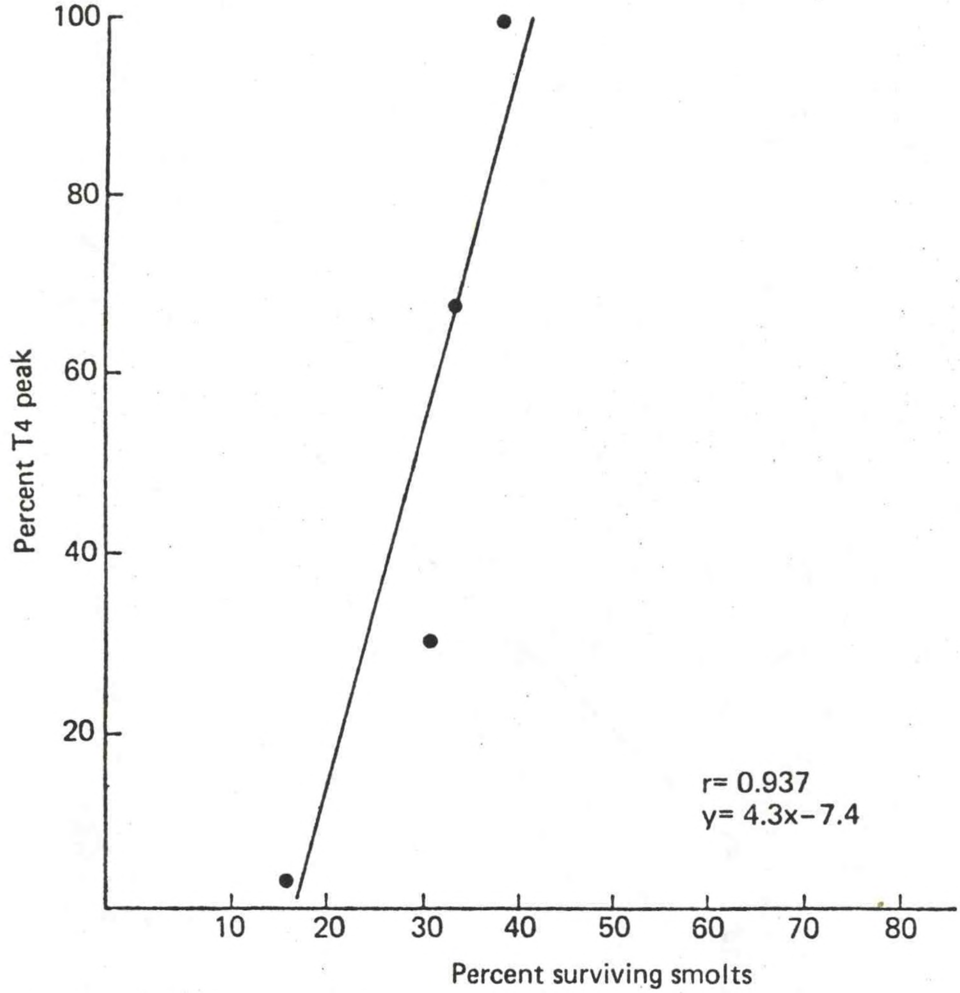


Figure 6.--Regression and analysis of the relationship betwen plasma T_4 concentrations and percent surviving smolts at termination of study in yearling baseline coho salmon test groups.

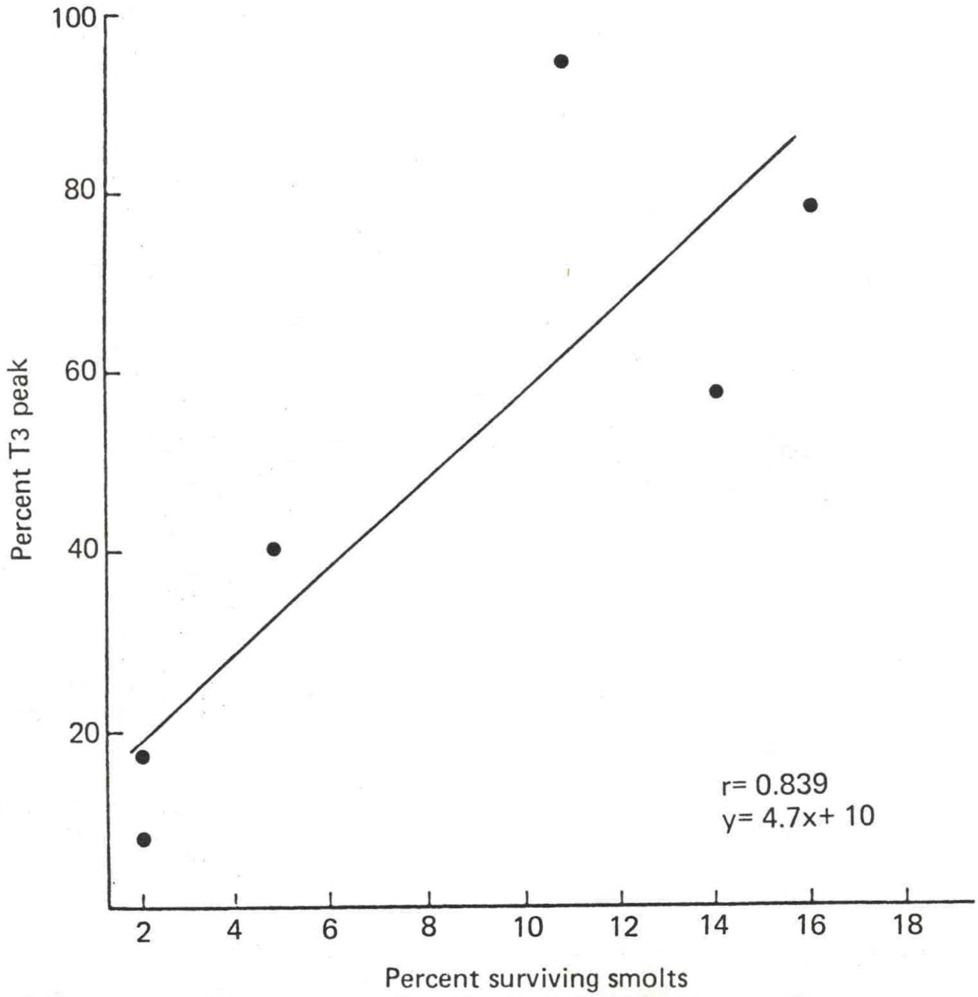


Figure 7.--Regression analysis of the relationship between plasma T_3 concentrations and percent surviving smolts at termination of study in 0-age baseline coho salmon test groups.

coho salmon (Folmar et al. 1979) and extend these observations with respect to 0-age fish. The developmental significance of these relationships is still unclear. At the time of seawater transfer, some groups of 0-age fish had the characteristic appearance of a smolt; however, their seawater survival was extremely poor. The early increase of plasma T_4 in the growth accelerated 0-age fish may have been sufficient to induce those receptor sites involved with growth and regulation of purine deposition in the integument; however, the plasma T_4 peak may not have been of sufficient duration to facilitate seawater entry and survival. In our studies with yearling coho and spring chinook salmon, we have found that the best survival occurs when fish are transferred to seawater on the descending portion of the plasma T_4 peak. We have suggested that increased survival during this period may have resulted from an antagonistic relationship between plasma concentrations of T_4 and prolactin secretion (see Hatchery Studies section). In the 0-age fish, the correlation of survival with the plasma T_3 peak suggests that there may be a similar antagonistic relationship between plasma T_3 concentrations and prolactin secretion. However, T_3 may be less efficacious than T_4 in reducing prolactin secretion, resulting in greater prolactin influence and therefore reduced seawater survival. These interpretations must be considered conjectural until further studies can be conducted. Our results point to the need for additional studies concerning the dose-time dependent maturational effects of thyroid hormones and the interrelationships of thyroid hormones with other endocrine principles during the period of smoltification and seawater adaptation.

Hatchery Studies

Although the actual specific activities varied somewhat, gill Na^+-K^+ ATPase exhibited similar developmental patterns during freshwater smoltification in the yearling coho and spring chinook salmon and steelhead. Also, at seawater entry the measured Na^+-K^+ ATPase activities were somewhat different, but the acclimation patterns were generally the same for all three species as represented by coho salmon test groups from Big Creek Hatchery (Figures 8 and 9). Gill Na^+-K^+ ATPase activities were found to be significantly correlated with both plasma T_4 and T_3 in coho ($P \leq 0.01$) and spring chinook ($P \leq 0.01$) salmon in both fresh water and seawater. However, this relationship did not exist between Na^+-K^+ ATPase and the thyroid hormones in steelhead. The significance of these relationships in development and seawater acclimation of coho salmon has been previously described (Folmar et al. 1979). As in that study, there were no statistically significant relationships between any of the Na^+-K^+ ATPase measurements made in fresh water or seawater for all three species, and the number of surviving or smolted fish in seawater at termination of the study (Table 1).

The magnitudes of change in plasma T_4 concentrations varied between species, however, all of the experimental groups, where we had complete profiles, exhibited a well-defined increase in plasma T_4 levels during smoltification as represented by Big Creek coho salmon (Figure 10). The significance of these changes in coho salmon have been previously discussed (Folmar et al. 1979). Also, in that report, we showed a significant relationship between the area beneath the T_4 curve and survival of the experimental fish after 6 months in seawater. Unfortunately, this year our

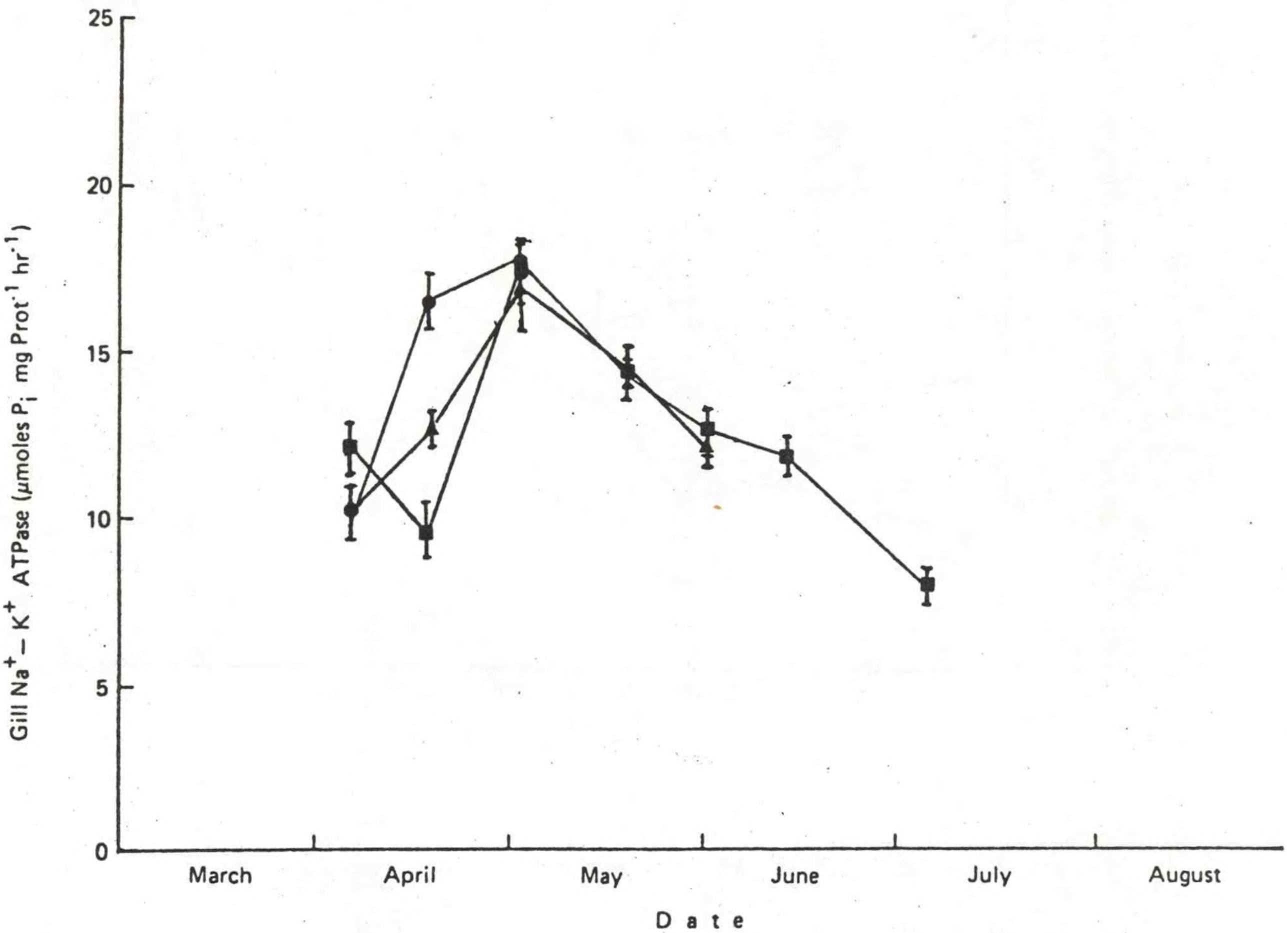


Figure 8.--Gill Na^{+}-K^{+} ATPase activities vs time for three serial releases [BC I (●), BC II (▲), BC III (■)] of coho salmon at the Big Creek during smoltification in fresh water.

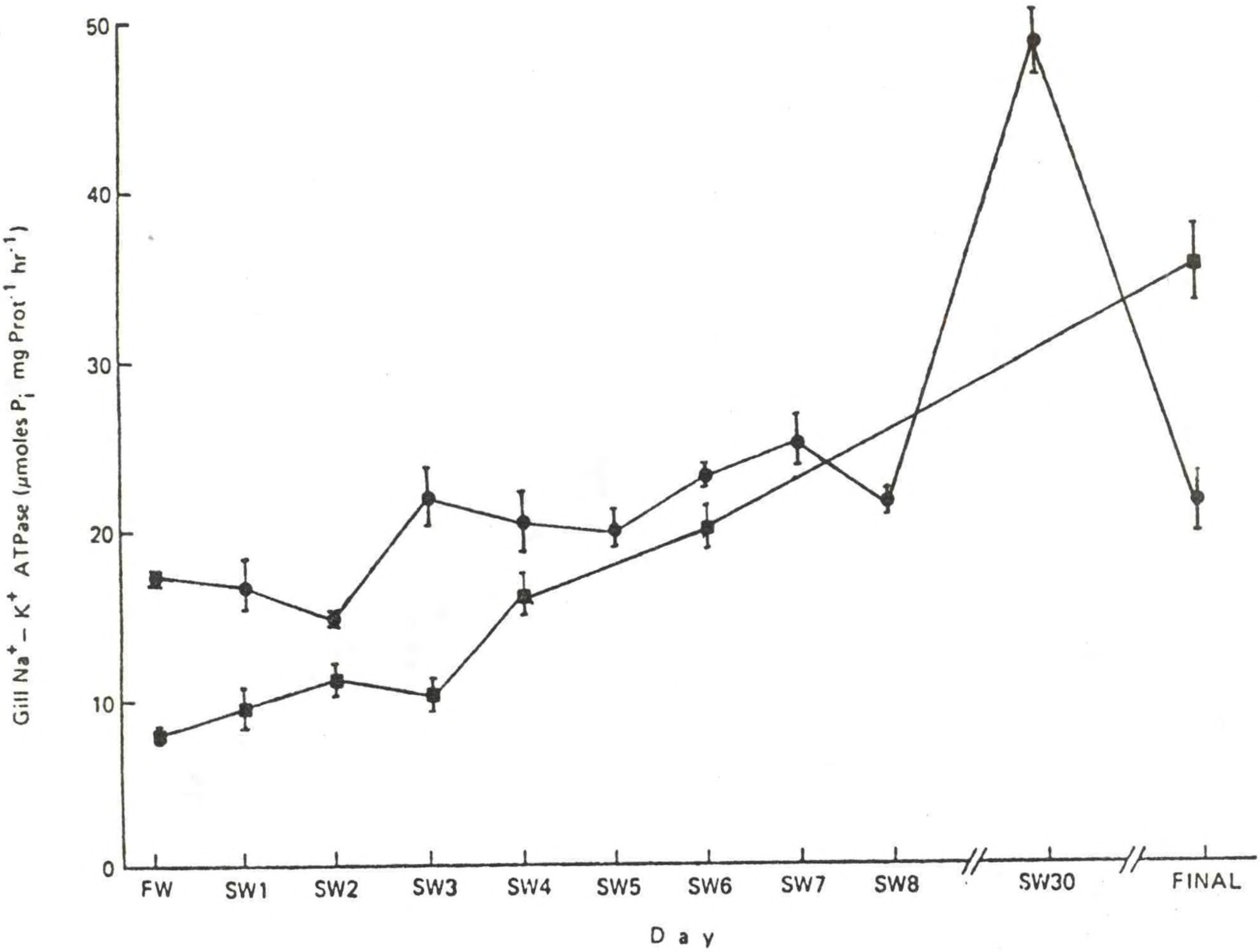


Figure 9.--Gill Na^{+}-K^{+} ATPase activities vs time for the first (●) and third (■) serial releases of coho salmon from Big Creek Hatchery during their period of seawater acclimation. For time and size of fish at seawater entry and termination, see Table 1.

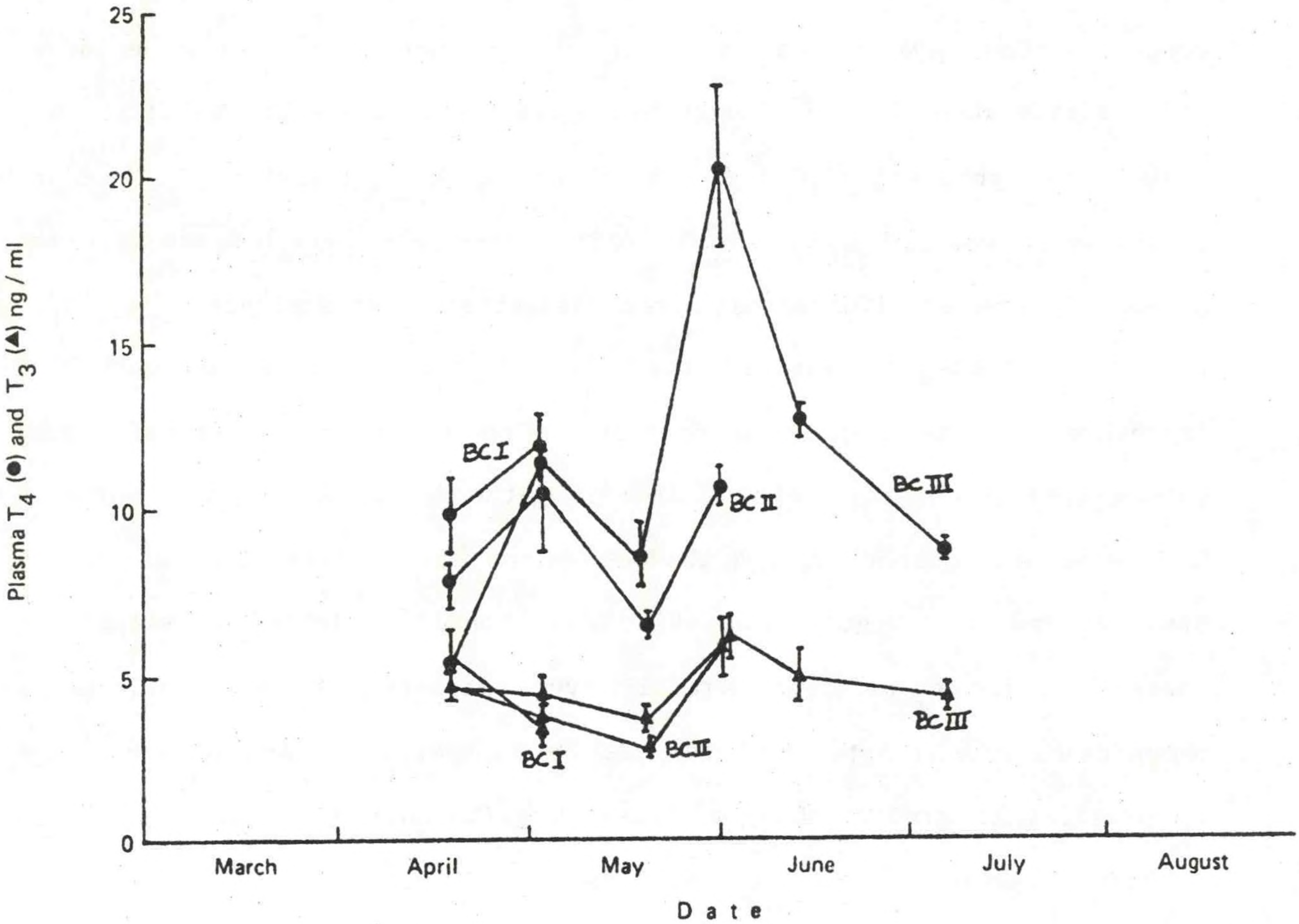


Figure 10.--Plasma T_4 and T_3 concentrations vs time for three serial releases (BC I, BC II, and BC III) of coho salmon at the Big Creek Hatchery during smoltification in fresh water.

sampling schedule did not commence early enough to obtain a complete plasma T_4 profile for all of the experimental fish. Therefore, we were unable to calculate areas beneath the individual plasma T_4 curves. However, we did find a significant relationship between the plasma T_4 concentrations at the time of seawater transfer (as a percentage of the peak plasma T_4 concentrations) and percent survival at termination of the experiment. This relationship was significant by regression analysis for yearling coho salmon test groups ($P \leq 0.01$) (Figure 11). Data suggested that the same relationship was probably true for spring chinook salmon but not true for steelhead; however, limited data precluded statistical analysis.

We continue to support the use of plasma T_4 measurements in freshwater fish as an index to predict the optimal period to transfer coho salmon into seawater. As more data is gathered, plasma T_4 may prove to be a good predictor of spring chinook salmon seawater readiness. At the present time, we suggest that this test should be limited to situations where fish are transferred directly from hatcheries to seawater, as in ocean ranching or net-pen culture. Before suggesting the use of the plasma T_4 profiles to predict release dates from Columbia River hatcheries, it will be necessary to evaluate the data from the adult returns of the 1978 and 1979 releases.

Plasma concentrations of T_3 were generally below those of T_4 in all test groups (Figure 10). The lack of a consistent pattern of plasma T_3 concentrations during smoltification of yearling fish precludes its consideration as an index to smoltification.

Plasma Na^+ and Cl^- concentrations did not change during the freshwater sampling period in either the baseline or species comparison studies as represented by Big Creek coho salmon (Figure 12). This

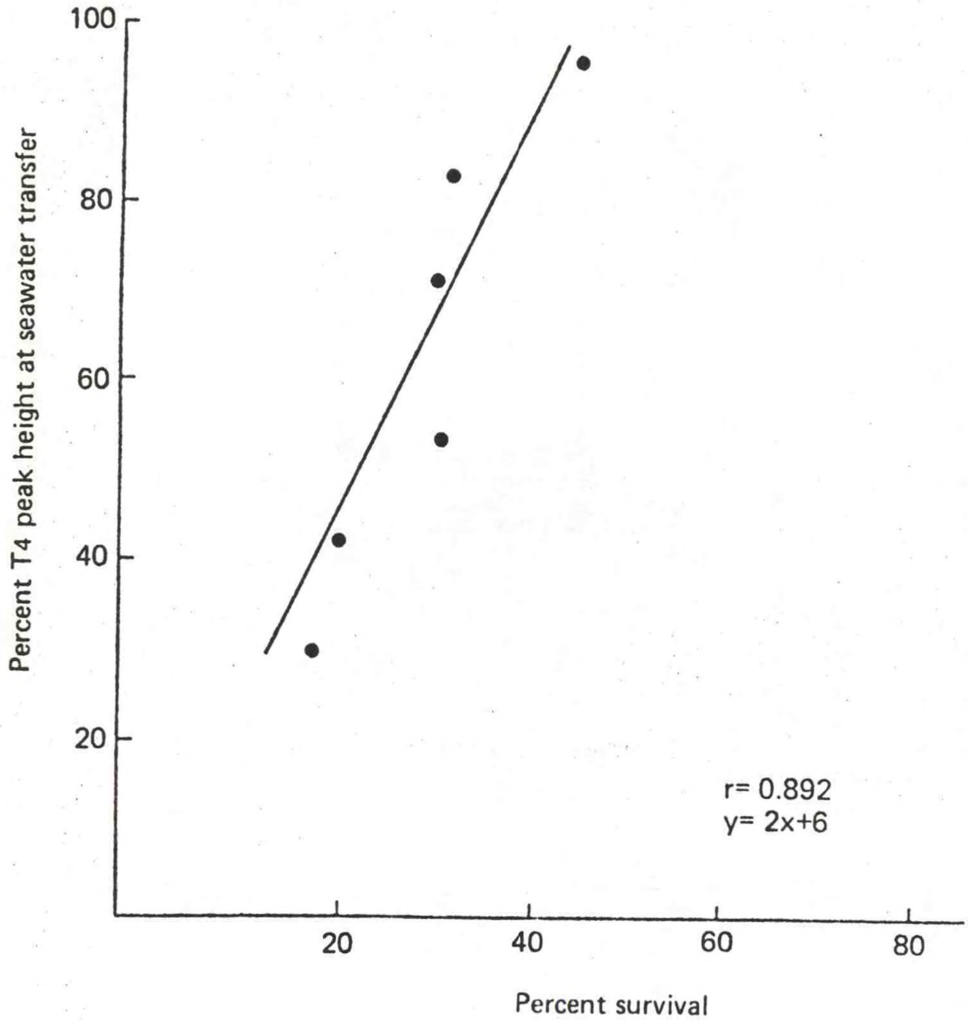


Figure 11.--Regression analysis of the relationship between plasma T_4 concentrations and percent surviving smolts in yearling coho salmon.

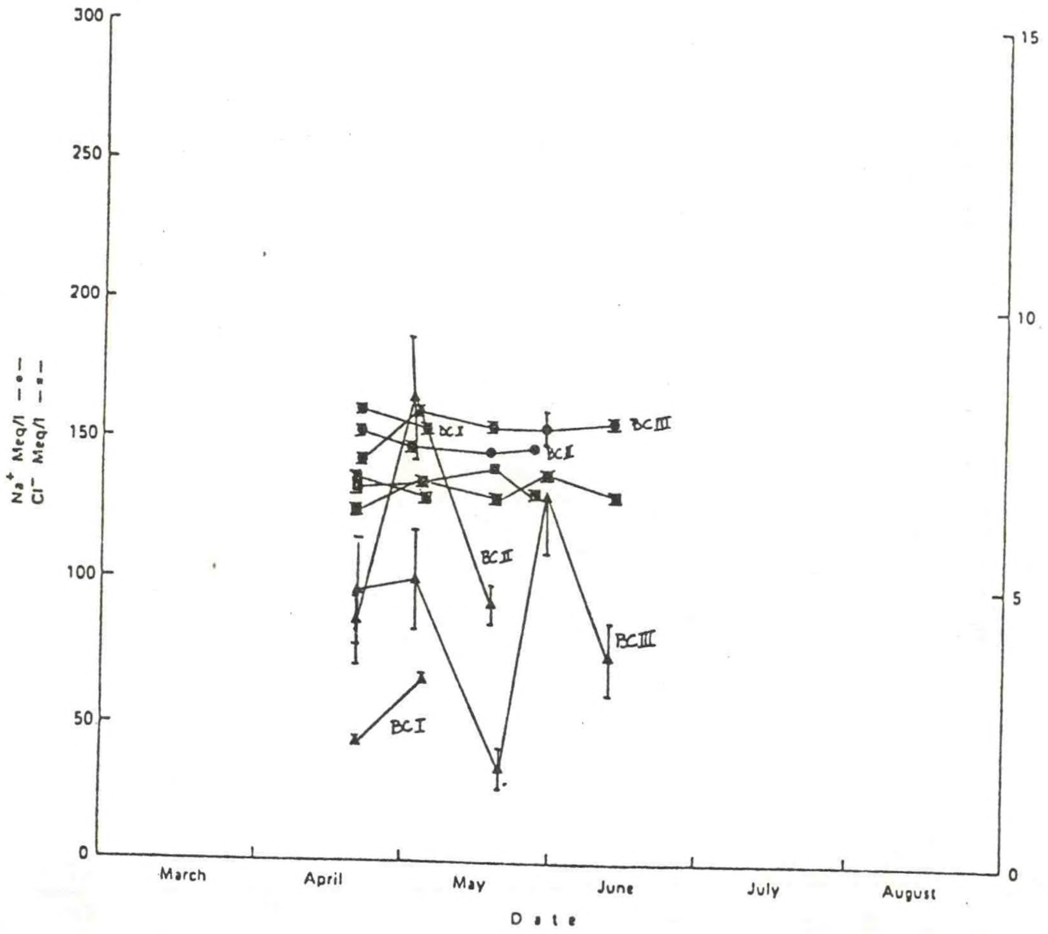


Figure 12.--Plasma Na^+, Cl^-, and K^+ concentrations vs time for three serial releases (BC I, BC II, and BC III) of coho salmon at the Big Creek Hatchery during smoltification in fresh water.

relationship has been previously discussed (Folmar et al. 1979). The erratic fluctuations of plasma K^+ values are believed to be stress related (Figure 12). Where fish were crowded in the sampling buckets or subjected to low dissolved oxygen concentrations, the plasma K^+ concentrations increased with each sample taken. The increased plasma levels may have resulted from leaching of K^+ from the heart muscle (Wedemeyer 1980, personal communication). Steelhead showed fewer changes and changes of lesser magnitude than those observed for the coho and chinook salmon. The steelhead were much larger fish, but not as crowded, and were sampled by withdrawing blood from the caudal artery with a vacutainer rather than cutting off the tail as in the coho and chinook salmon.

At seawater entry, plasma Na^+ and Cl^- concentrations increased for 24-72 h., decreased and then stabilized at levels commensurate with seawater residence in most test groups as represented by Big Creek coho salmon (Figures 12 and 13). As with our previous study (Folmar et al. 1979), we found no relationship between plasma electrolytes and gill Na^+-K^+ ATPase or plasma thyroid hormone concentrations in any of the three species of fish. Fluctuations in plasma K^+ concentrations of the fish in seawater may also have been caused by our sampling procedures.

Plasma Ca^{++} concentrations fluctuated to varying degrees among the three species in fresh water as represented by Big Creek coho salmon (Figure 14). The mechanisms by which plasma Ca^{++} concentrations are regulated in teleost fishes have not been established. In coho and spring chinook salmon, plasma Ca^{++} concentrations showed a negative correlation ($P \leq 0.05$) with plasma T_4 concentrations. Plasma Ca^{++} concentrations

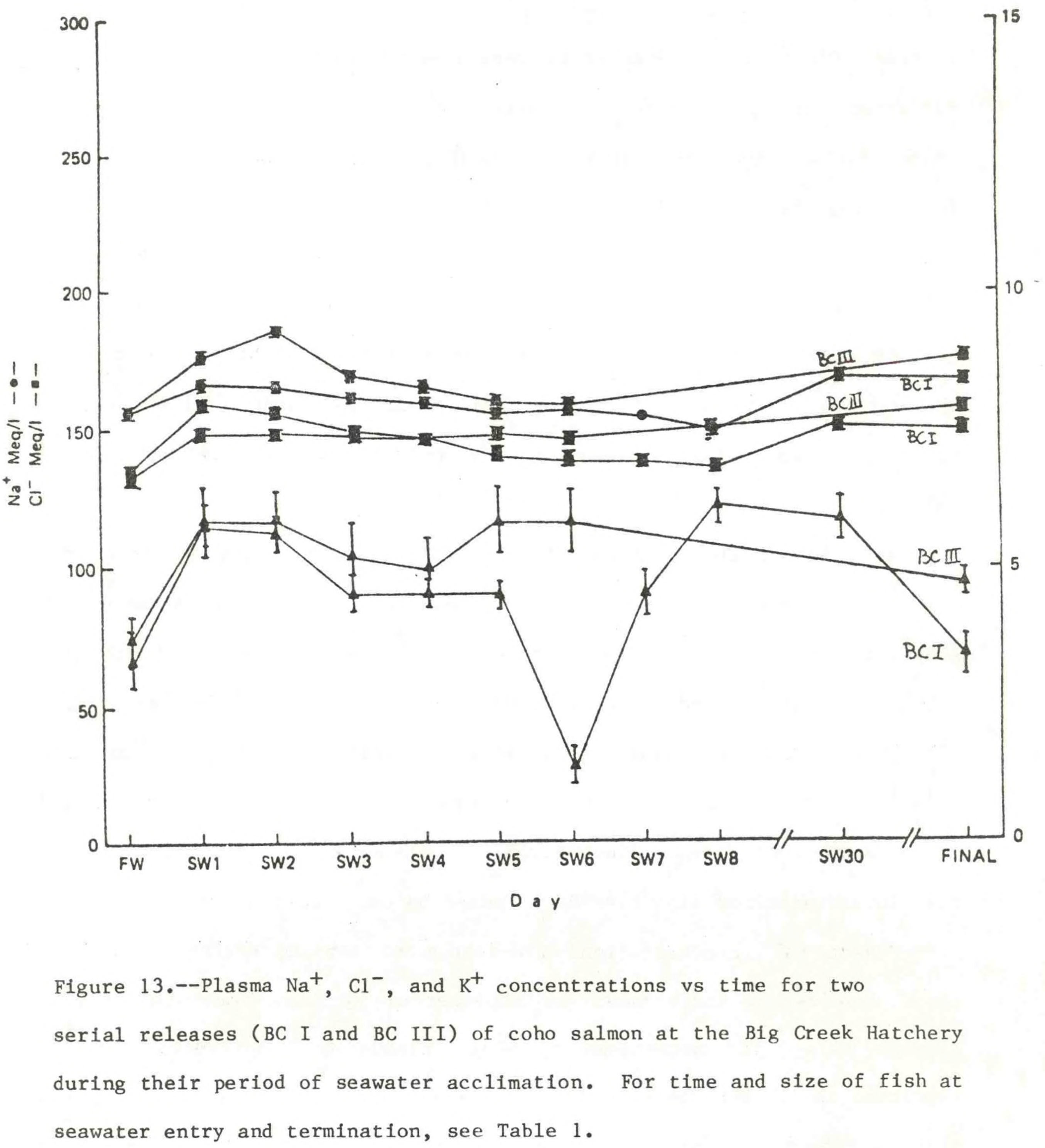


Figure 13.--Plasma Na^+, Cl^-, and K^+ concentrations vs time for two serial releases (BC I and BC III) of coho salmon at the Big Creek Hatchery during their period of seawater acclimation. For time and size of fish at seawater entry and termination, see Table 1.

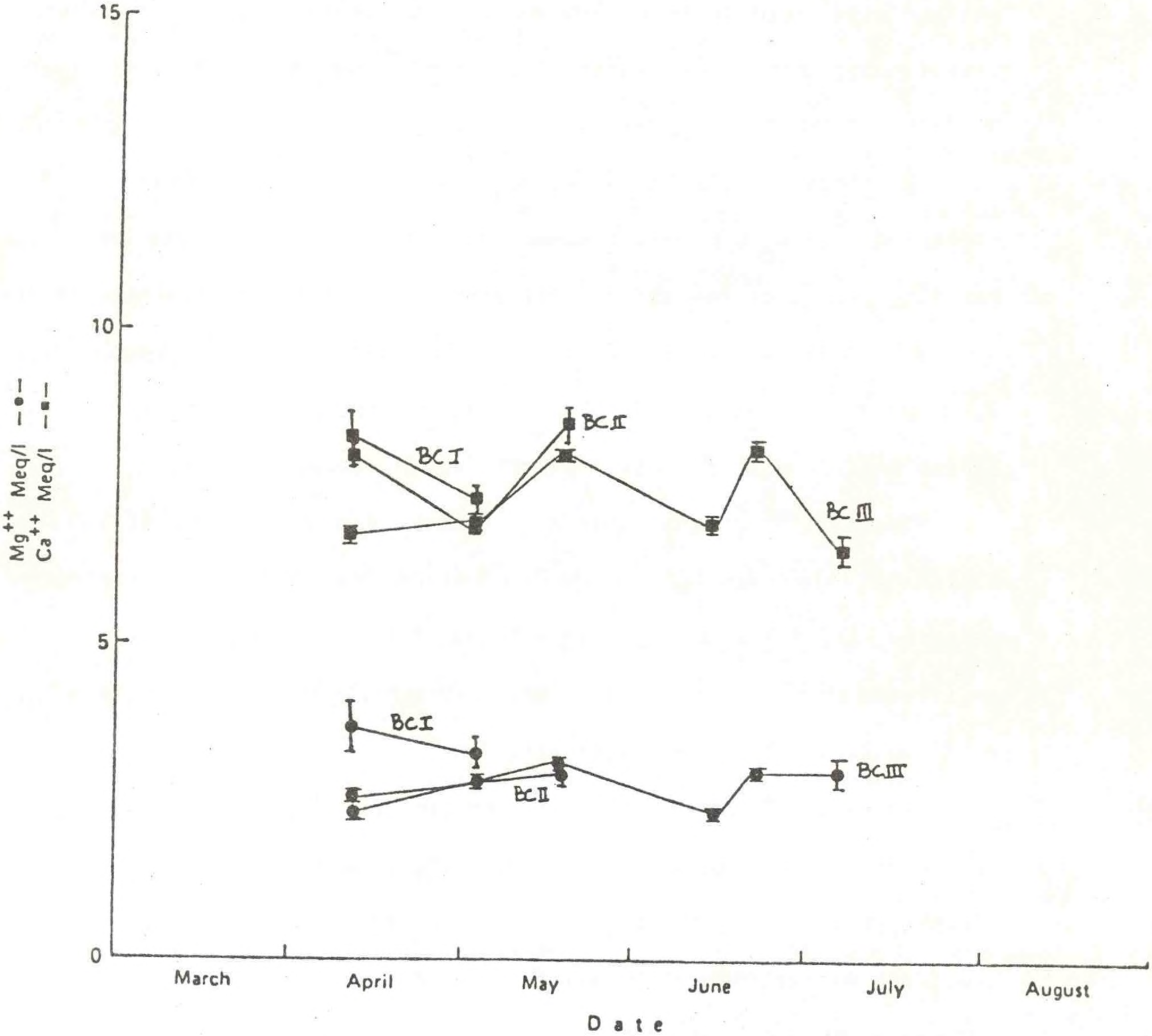


Figure 14.--Plasma Ca^{++} and Mg^{++} concentrations vs time for three serial releases (BC I, BC II, and BC III) of coho salmon at the Big Creek Hatchery during smoltification in freshwater.

decreased during the T_4 surge, then increased at or near the end of the T_4 peak. The maintenance of increase of plasma Ca^{++} levels is possibly regulated by prolactin. The observed decreases in plasma Ca^{++} concentrations near the end of the T_4 peak may have resulted from an antagonistic relationship between T_4 and prolactin. This antagonistic relationship has been previously demonstrated in amphibians (Bern and Nicoll 1969). No observable change was noted in plasma Ca^{++} concentrations in Chelan steelhead and only a decrease in Tucannon steelhead. The sea patterns may have been partially due to a shorter sampling period or possible differences in endocrine mechanisms. There was no opportunity to observe the plasma Ca^{++} concentration changes after the T_4 increase. Secondly, the T_4 peaks of the steelhead were of a much lesser magnitude than those observed for the other species.

Plasma Mg^{++} concentrations in freshwater acclimated fish tended to follow patterns similar to those observed for plasma Ca^{++} concentrations (Figure 14). The changes in plasma Mg^{++} were generally of a lesser magnitude than those observed for plasma Ca^{++}. The method of plasma Mg^{++} regulation in teleosts is unclear.

Plasma Ca^{++} and Mg^{++} concentration fluctuated at seawater entry for coho and chinook salmon and steelhead; however, both divalent electrolytes had stabilized by the third or fourth day of seawater residence as represented by Big Creek coho salmon (Figure 15). The initial changes observed at seawater entry were probably caused by concentration gradients between seawater and the internal fluids of the fish (Parry 1966). The three to four days before stabilization may represent the period required for the initiation of drinking (Sharrat et al. 1964) and a

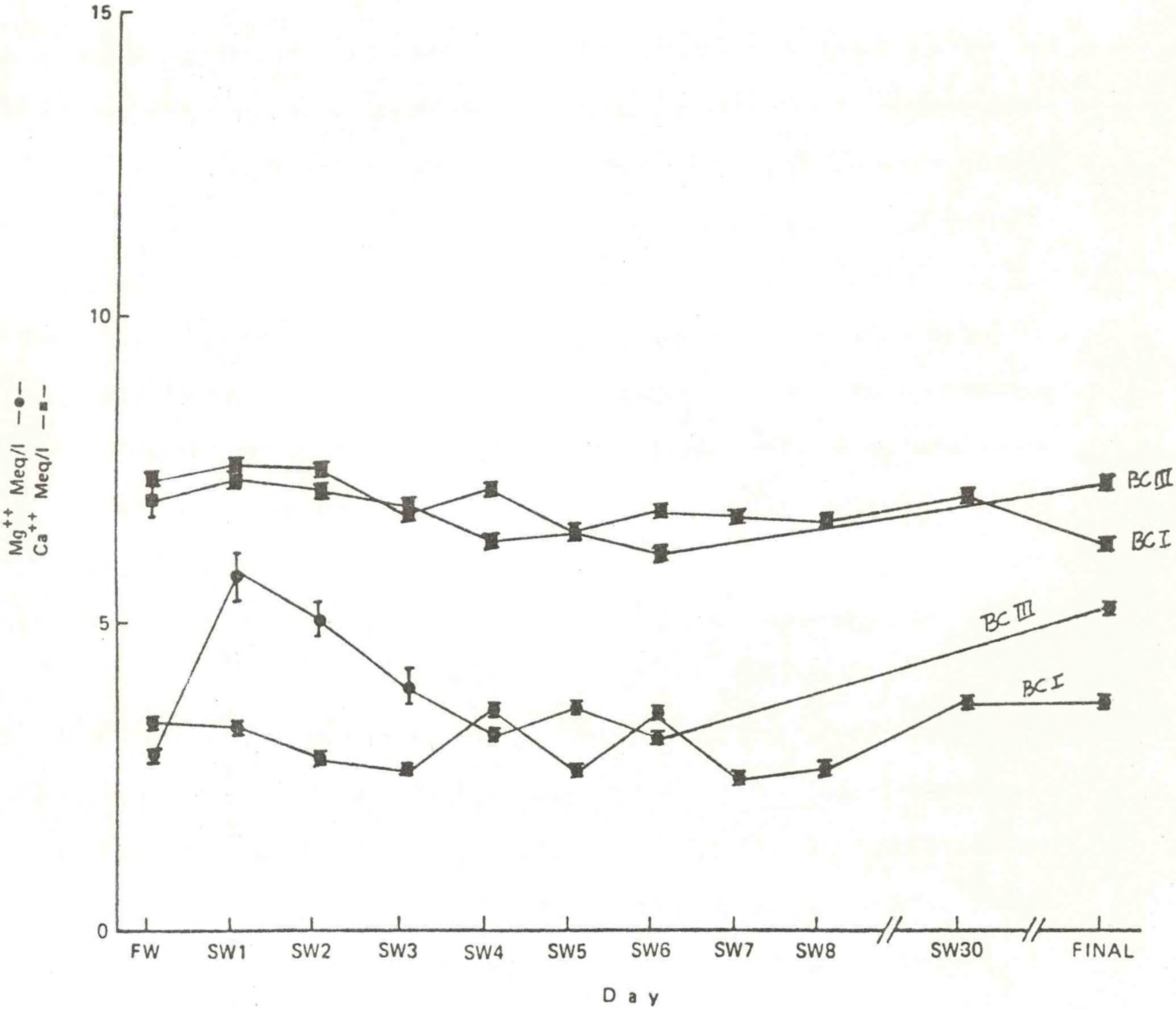


Figure 15.--Plasma Ca^{++} and Mg^{++} concentrations vs time for two serial releases (BC I and BC III) of coho salmon at the Big Creek Hatchery during their period of seawater acclimation. For time and size of fish at seawater entry and termination, see Table 1.

shift (prolactin to coritsol) in the endocrine regulation of divalent ions in the hindgut (Johnson 1973, Folmar and Dickhoff 1980).

There were no statistically significant relationships between any measurements of the plasma electrolytes in fresh water or seawater and the number of surviving or smolted fish at termination of seawater residence (Table 1).

In previous reports (Folmar and Dickhoff 1979, 1980; Folmar et al. 1979), we have suggested that gill Na^{+}-K^{+} ATPase may be directly activated during smoltification by thyroxine. The results of this year's study suggest an alternate hyopthesis for coho and chinook salmon. In all of the yearling coho and chinook groups the increase in plasma T_4 was accompanied by a decrease in plasma Ca^{++} levels. Since plasma Ca^{++} levels were increasing, presumably mediated by prolactin at periods other than during increase in T_4, this suggests that there may be an antagonistic relationship between T_4 and prolactin. Prolactin has been demonstrated to be inhibitory of Na^{+}-K^{+} ATPase in other teleosts (Pickford et al. 1970). Therefore, T_4 may facilitate an increase in Na^{+}-K^{+} ATPase activity through the inhibition of prolactin action. Also, since the optimal period for successful seawater entry appears to correspond to the period of elevated T_4 levels and depressed plasma Ca^{++} levels, it is attractive to speculate that prolactin is the antagonistic factor to successful seawater adaptation in the early spring or late summer. Unfortunately, we cannot test this hypothesis since there is currently no reliable assay for plasma prolactin in salmonids.

Despite similarities in the appearance of the Na^{+}-K^{+} ATPase and T_4 profiles between coho and chinook salmon and steelhead, there were no statistically significant relationships between these parameters in steelhead. The steelhead showed no statistical relationship between plasma T_4 concentrations in freshwater and seawater survival. There were few or no changes in plasma Ca^{++} during smoltification of steelhead. The survival and contribution to the fishery of the steelhead was at best less than 50% of any other group. In previous seawater transfer experiments (unpublished) steelhead have always shown poor survival, much less than coho or spring chinook salmon. At present, we have no explanation for these differences, nor are we satisfied that any of the physiological measurements made during this study could predict optimal seawater transfer times for steelhead. It appears from our preliminary findings that the underlying physiological mechanisms controlling seawater adaptation and survival of steelhead are fundamentally different from those of coho and chinook salmon and, therefore, require additional study.

LITERATURE CITED

Bern, H. A., and C. S. Nicoll.
1969. The zoological specificity of prolatins. In: La Specificite Zoologique des Hormones Hyopphysaires et de Leurs Activities. Colloques Internationaux du Centre National de la Recherche Scientifique, No. 177, pp. 193-203. C.N.R.S. Paris.

Folmar, L. C., and W. W. Dickhoff.
1979. Plasma thyroxine and gill Na^{+}-K^{+} ATPase changes during seawater acclimation of coho salmon, Oncorhynchus kisutch. Comp. Biochem. Physiol. 63A:329-332.

Folmar, L. C., W. S. Zaugg, and W. W. Dickhoff.
1979. A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead, Proj. Rep. 817, Pacific Northwest Regional Commission. Appendix E. 38 pp.

Folmar, L. C., and W. W. Dickhoff.
1980. The parr-smolt transformation (smoltification) and seawater adaptation for salmonids. A review of selected literature. Aquaculture 21(1):1-37.

Johnson, D. W.
1973. Endocrine control of hydromineral balance in teleosts. Amer. Zool. 13:799-818.

Mighell, J. L.
1979. A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead, Proj. Rep. 817, Pacific Northwest Regional Commission. Appendix D. 11 pp.

Parry, G.
1966. Osmotic adaptation in fishes. Biol. Rev. 41:392-444.

Pickford, G. E., R. W. Griffeth, J. Torretti, J. Hendler, and F. H. Epstein.
1970. Branchial reduction in renal stimulation of (Na^{+}-K^{+}) ATPase by prolactin in hypophysectionized killifish in freshwater. Nature (Lond.) 228:378-379.

Sharrat, B. M., D. Bellamy, and I. Chester Jones.
1964. Adaptation of the silver eel (Anguilla anguilla L.) to seawater and to artificial media together with observations on the role of the gut. Comp. Biochem. Physiol. 30:397-413.

APPENDIX G

CHANGES IN SWIMMING STAMINA AND SURVIVAL RELATED TO SWIMMING FATIGUE IN RESPONSE TO DIRECT SEAWATER ENTRY DURING THE PARR-SMOLT TRANSFORMATION FOR COHO SALMON

by

Tom A. Flagg

and

Earl F. Prentice

September 1980

INTRODUCTION

Coho salmon (Oncorhynchus kisutch) undergo a distinct parr-smolt transformation which physiologically pre-adapts them for seawater residence. This change is transitory in that salinity tolerance develops prior to and during smoltification and decreases if the fish does not enter seawater (Hoar 1976). Several investigators have emphasized the importance of this transformation to overall seawater adaptability and survival (Baggerman 1960; Conte et al. 1966; Hoar 1976; Clarke and Nagahama 1977; Woo et al. 1978; Folmar 1979). However, little is known about the relationship between smoltification and the ability of fish to cope with severe physical stress, such as swimming fatigue, at transfer to seawater.

Direct seawater transfer may have an initial debilitating effect on salmonids; entry to seawater (>28 °/oo) causes immediate ionic, hormonal, and enzymatic imbalances that re-equilibrate as fish, e.g. coho salmon, adapt to the saline environment (Conte et al. 1966; Miles and Smith 1968; Clarke and Blackburn 1978; Folmar and Dickhoff 1979). In addition, direct seawater transfer may initially reduce the swimming stamina and overall behavioral activity of salmonids (Huntsman and Hoar 1939; Houston 1957; Houston 1959; Flagg and Smith 1979).

Compromises in swimming stamina, associated with the seawater transfer of Pacific salmon, are believed to be physiologically motivated. Houston (1959) indicated that muscular inefficiency associated with seawater transfer is primarily due to ionic imbalances causing inhibitions of the neuromuscular system. This compromise in muscular activity may occur through a combination of an increase in the plasma magnesium concentration (causing inhibition of the pre-synaptic transmitter substance acetylcholine) and/or changes in the plasma chloride to sodium ratios (modifying cellular pH and, consequently, enzyme activity) (Houston 1959). Increases in metabolic energy demands during the adjustive phase of seawater adaption can also be an important factor in the depression of locomotory performance (Houston 1959). Smoltification status may influence the magnitude of this depression in swimming stamina since there appears to be a period during the peak of smoltification in which coho salmon enter seawater without locomotory compromises (Flagg and Smith 1979).

Muscular inefficiency at the time of seawater entry is potentially detrimental to the fish's adjustment to the saline environment. The depression of locomotory performance may impede ocean migration and feeding and increase susceptibility to predation. These compromises may also lower resistance to stress and disease in seawater.

The present study investigated the relationship between locomotory performance and smoltification status in coho salmon. The goals of this study were to: (1) investigate changes in swimming stamina of yearling coho salmon in fresh water and seawater during various stages of the parr-smolt transformation, (2) determine if the parr-smolt transformation influences the ability to survive severe physical stress (swimming fatigue), and (3) determine if the swimming stamina level at seawater entry is related to long-term survival in seawater.

METHODS AND MATERIALS

Yearling Toutle River salmon designated as baseline test fish were reared under known conditions at the National Marine Fisheries Service's (NMFS) Seattle laboratory (Appendix E). Subsamples (n = 200) of these fish were transferred to seawater ($\approx$ 29 °/oo) at the Manchester Marine Experimental Station near Manchester, Washington on a serial entry schedule--eight entries from 20 March to 24 July 1979 (Table 1). Two subsequent entry groups were not evaluated.

Swimming stamina tests were conducted on random samples (n = 20 to 40 fish) of each serial entry group at four testing periods: (1) just prior to seawater entry; (2) during the first week of seawater residence (normally at days 1, 2, and 3); (3) at the end of the second week of seawater residence (normally at days 12, 13, and 14); and (4) at the end of the third week of seawater residence (normally at days 19, 20, and 21) (Table 2). At the time of testing the state of smoltification was determined for each fish using external characteristic criteria developed by NMFS personnel (Prentice et al. 1979). The predominant stage of smoltification (Table 1) was determined by comparison of both visual and biochemical [e.g., gill sodium-potassium-activated adenosinetriphosphatase (Na^+-K^+ ATPase) and plasma thyroxine (T_4) concentrations] indicators of smoltification.

Swimming stamina tests were conducted in a modified version of the Blaska respirometer-stamina chamber described by Smith and Newcomb (1970). Each of the two chambers were divided into four compartments with a common electrified screen at the downstream end assuring maximum fish performance (Figure 1). Each fish was anesthetized (tricaine methanesulfonate) and its fork length was determined. One fish was placed in each compartment. After a 1-hour recovery period the initial water velocity was set at 1.5 body lengths per second (l/s) and increased 0.5 l/s every 15 minutes until all four fish reached fatigue (i.e., could no longer hold position in the current and collapsed against the electrified screen). The l/s value was based upon the mean length of the four fish per test.

Table 1.--Dates of seawater transfer, predominant stage of smoltification, and mean length and weight at seawater transfer for the yearling baseline coho salmon serial entry test groups.

Test group[d]	Seawater entry date	Predominant[a] stage of smoltification	Mean[b] length	Mean[c] weight
1	20 March 1979	transitional	137.0 ± 12.3	29.7 ± 7.8
2	3 April 1979	transitional	140.7 ± 13.2	30.7 ± 9.1
3	17 April 1979	pre-optimum smolt	145.7 ± 11.6	34.8 ± 8.3
4	1 May 1979	near-optimum smolt	151.2 ± 12.3	38.2 ± 9.4
5	15 May 1979	post-optimum smolt	155.7 ± 10.8	41.8 ± 9.1
6	30 May 1979	post-optimum smolt	158.8 ± 12.1	44.6 ± 11.0
7	12 June 1979	late-smolt	163.9 ± 12.0	50.7 ± 11.8
8	24 July 1979	post-smolt	177.8 ± 13.2	68.7 ± 16.0

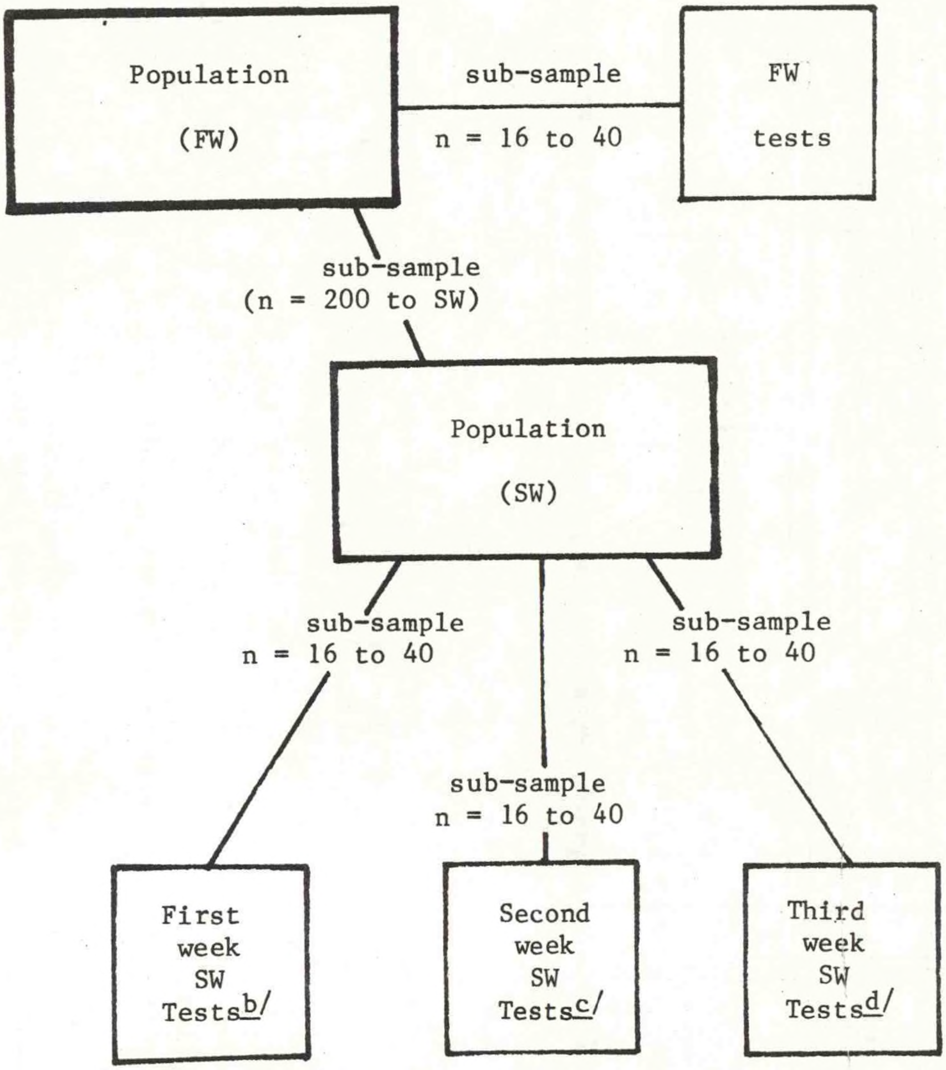
a/ Determined by correlation of visual criteria and biochemical profiles.

b/ Mean fork length (mm) ± one standard deviation.

c/ Mean weight (g) ± one standard deviation.

d/ 1 - 8 indicates successive serial entry groups, n = 150 (Appendix D).

Table 2.--Generalized sampling procedure for each of eight yearling baseline coho salmon serial entry test groups. Subsamples were monitored for 7 days after the swimming fatigue tests to determine post-test survival. [a/]

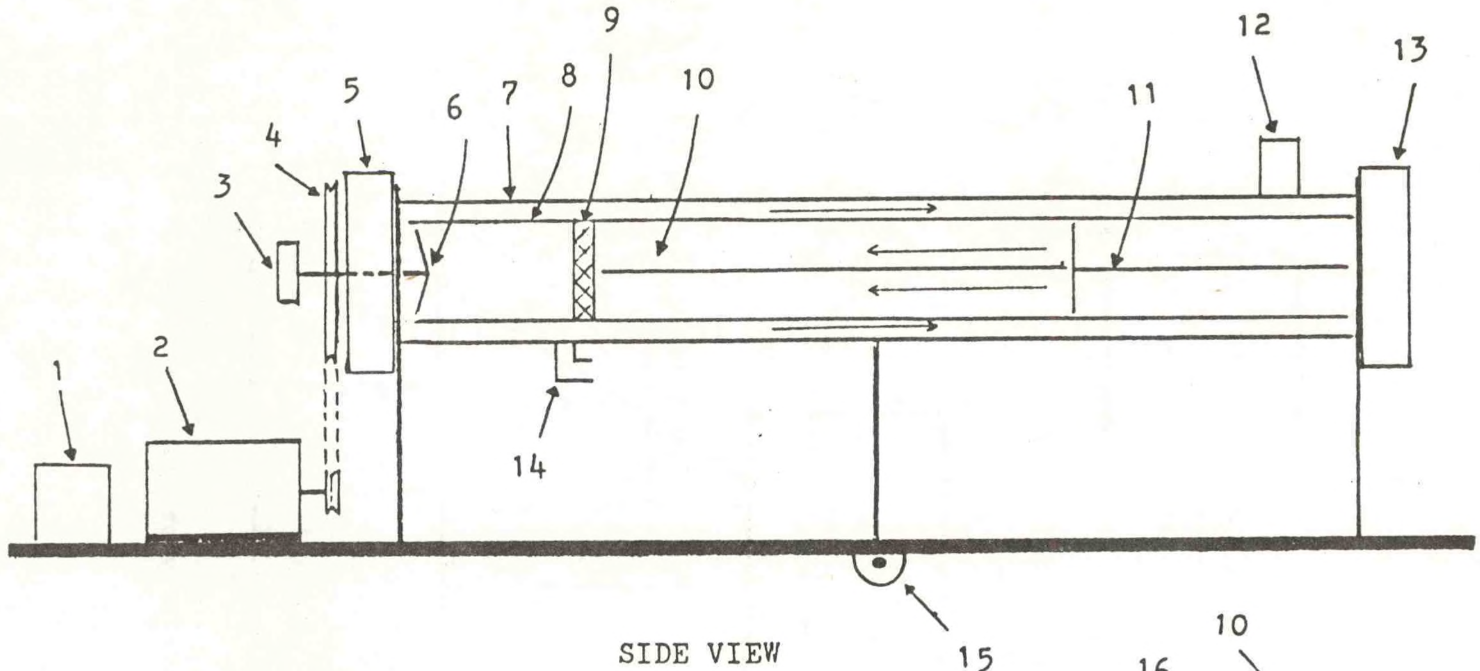


a/ FW = fresh water, SW = seawater, n = 20 to 40 for swimming fatigue tests and n = 16 to 32 for post-test survival (see Table 3)

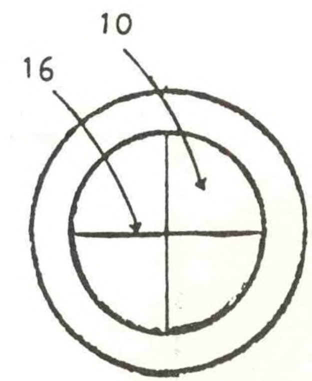
b/ Normally at days 1, 2, and 3

c/ Noramlly at days 12, 13, and 14

d/ Normally at days 19, 20, and 21



SIDE VIEW



END VIEW

1. Variable speed control
2. Motor
3. Tachometer
4. Pulley
5. End plate
6. Propeller
7. Outer tube (Plexiglas)
8. Inner tube (Plexiglas)
9. Electrified screen
10. Test compartment
11. Removable vane
12. Outflow
13. End plate (removable for fish loading)
14. Inflow
15. Axle for tilting chamber
16. Compartment divider

Figure 1.--Diagram of a modified Blaska respirometer-stamina chamber, showing side and end views. For loading, the chamber is tilted, partially filled with water, and end plate and vane are removed. Fish are placed in the test compartments, vane and end plate are replaced, and chamber is leveled and filled with water. Water flow is produced with motor driven propeller and varied via motor speed controller. Direction of water flow is toward propeller in inner tube, water is turned at the end plate, and returned through the space between the inner and outer tubes (see arrows).

The swimming speed of each fish was calculated from the relationship between the mean length of the four fish and the length of the individual fish to the water flow within the chamber by the formula:

$$S_p = (l_i/l_{ii}) \times V$$

where: S_p = swimming speed of individual fish (l/s)

l_i = mean length of the four fish (mm)

l_{ii} = length of the individual fish (mm)

V = water velocity in the chamber (l/s)

Swimming speed was corrected for the effects of solid blocking (all fish represented an area greater than 10% of the cross-sectional area of their swimming compartment) using the formula described by Bell and Terhune (1970):

$$V_f = V_t \left(1 + \frac{A_o/A_t}{1-A_o/A_t}\right)$$

where: V_f = effective velocity (l/s)

V_t = average velocity through the empty test section (l/s)

A_o = maximum cross-sectional area of the object in the test section (mm^2)

A_t = test section area (mm^2)

A swimming stamina profile (U-critical) was established for each test group, using the swimming speed at fatigue and the time of fatigue, by the methods described in Beamish (1978):

$$\text{U-critical} = U_i + (t_i/t_{ii} \times U_{ii})$$

where: U-critical = critical swimming speed (l/s)

U_i = highest velocity maintained for the prescribed period (l/s)

U_{ii} = velocity increment (l/s)

t_i = time (in minutes) that the fish swam at the fatigue velocity

t_{ii} = prescribed period of swimming (in minutes)

A 7-day post-test survival profile was developed for each test group (n = 16 to 32 fish) and compared to nontested controls. Fresh mortalities and moribund fish were periodically necropsied to determine cause of death.

The results of this study (Tables 3 and 4) were compared to the biochemical indicators of smoltification (Appendix F) and to seawater survival information (Appendix B) for each baseline test group (Tables 5 and 6). Survival of each of the serially entered groups was monitored until the termination of the study (10 November 1979). Because of changing environmental and physiological parameters during the seawater study period, the survival comparisons were only considered up to 90 days post-seawater entry. All data were subjected to analysis of variance comparisons (single classification and Scheffe's test for multiple contrasts) and Pearson's Product Moment Test of Correlation using the methods of Sokal and Rohlf (1969).

RESULTS AND DISCUSSION

The present study confirms that the transition from a hypo-osmotic (freshwater) environment to a hyper-osmotic (seawater) environment can severely compromise the swimming ability of coho salmon. The direct transfer from fresh water to seawater induced significant ($\alpha = 0.01$) depressions in swimming stamina (U-critical for the first seven of the eight serial entry groups (Table 7 and Figure 2). The first seven entry groups had, statistically, ($\alpha = 0.01$) the same degree of stamina depression at seawater entry, representing an average decrease in ability of 33% (Table 8). The freshwater swimming stamina of fish in the eighth test group was significantly ($\alpha = 0.01$) reduced from that of the previous groups

Table 3.--Swimming stamina levels (U-critical), 7-day post-test (swimming fatigue) survival, and 7-day control survival for the baseline coho serial entry groups.

Test group[a]	Test periods[b]											
	Freshwater survival			1st week seawater survival			2nd week seawater survival			3rd week seawater survival		
	U-crit (1/s)	F (%)	C (%)	U-crit (1/s)	F (%)	C (%)	U-crit (1/s)	F (%)	C (%)	U-crit (1/s)	F (%)	C (%)
1	3.3 ± 0.3 (20)	100.0 (16)	100.0 (16)	2.5 ± 0.8 (40)	50.0 (32)	92.6 (150)	2.7 ± 0.4 (24)	93.8 (16)	100.0 (135)	3.1 ± 0.3 (24)	100.0 (24)	100.0 (135)
2	3.3 ± 0.3 (34)	100.0 (16)	100.0 (16)	2.6 ± 0.3 (24)	70.8 (24)	95.3 (150)	3.0 ± 0.2 (24)	100.0 (24)	100.0 (143)	3.3 ± 0.4 (24)	100.0 (24)	100.0 (143)
3	3.2 ± 0.2 (24)	100.0 (16)	100.0 (16)	2.2 ± 0.5 (24)	87.5 (24)	97.3 (150)	3.1 ± 0.4 (24)	100.0 (24)	100.0 (146)	3.1 ± 0.3 (24)	100.0 (16)	100.0 (146)
4	3.5 ± 0.4 (24)	100.0 (24)	100.0 (24)	2.2 ± 1.0 (24)	91.7 (24)	100.0 (150)	2.6 ± 1.1 (24)	100.0 (16)	100.0 (150)	3.2 ± 0.3 (24)	100.0 (16)	100.0 (150)
5	3.5 ± 0.3 (23)	100.0 (16)	100.0 (16)	1.9 ± 1.0 (24)	83.3 (24)	98.7 (150)	2.5 ± 0.4 (24)	100.0 (16)	100.0 (148)	3.5 ± 0.5 (24)	91.7 (24)	97.9 (148)
6	3.5 ± 0.3 (24)	100.0 (16)	100.0 (16)	2.1 ± 1.0 (24)	70.8 (24)	100.0 (150)	2.7 ± 0.7 (23)	87.5 (16)	100.0 (150)	3.0 ± 0.5 (23)	100.0 (16)	100.0 (150)
7	3.3 ± 0.5 (24)	50.0[c] (16)	43.8[c] (16)	2.0 ± 1.1 (24)	66.6 (24)	98.6 (150)	2.8 ± 0.6 (24)	100.0 (16)	100.0 (148)	2.8 ± 0.5 (24)	100.0 (16)	100.0 (148)
8	2.3 ± 1.0 (23)	16.7[c] (24)	29.2[c] (24)	1.9 ± 1.0 (24)	66.6 (24)	99.3 (150)	2.8 ± 0.7 (24)	100.0 (24)	100.0 (149)	2.7 ± 0.6 (24)	95.8 (24)	98.0 (149)

a/ 1-8 indicates successive serial entry groups.

b/ F = fatigued (test fish), C = nonfatigued (control fish), number in parenthesis indicates sample size, Ucrit = U-critical (body lengths/second) ± one standard deviation.

c/ Freshwater mortalities apparently caused by equipment malfunction creating elevated temperatures in holding areas.

Table 4.--Mean length and mean water temperature at testing for the yearling baseline coho salmon serial entry test groups.

Test group[a]	Test periods[b/c]							
	Freshwater		1st week seawater		2nd week seawater		3rd week seawater	
	$\overline{X}$ length (mm)	$\overline{X}$ temp (°C)	$\overline{X}$ length (mm)	$\overline{X}$ temp (°C)	$\overline{X}$ length (mm)	$\overline{X}$ temp (°C)	$\overline{X}$ length (mm)	$\overline{X}$ temp (°C)
1	131.5 ±7.9	7.8	138.5 ±9.8	7.4	140.3 ±10.7	7.4	138.8 ±9.7	7.2
2	139.4 ±10.0	8.9	140.3 ±9.8	7.5	141.9 ±9.3	7.7	137.8 ±13.2	8.0
3	148.0 ±11.0	8.9	147.7 ±13.2	7.6	154.4 ±13.1	8.4	146.6 ±10.7	9.0
4	150.1 ±12.9	12.2	155.0 ±10.5	9.1	158.0 ±10.0	10.1	159.8 ±12.0	10.6
5	158.0 ±10.0	13.3	159.9 ±11.4	9.9	165.7 ±9.1	10.4	161.6 ±9.9	11.2
6	158.4 ±9.9	12.7	164.6 ±9.8	11.2	166.7 ±8.4	11.0	165.9 ±9.3	11.2
7	169.4 ±11.4	13.1	169.0 +10.9	12.1	172.9 ±9.9	12.2	174.4 ±8.2	13.1
8	175.2 ±9.1	13.5	178.8 ±13.2	15.5	182.0 ±13.3	15.1	182.8 ±11.6	14.5

a/ 1 - 8 indicates successive serial entry groups.

b/ $\overline{X}$ length = mean fork length (mm) ± one standard deviation, n = 20 to 40 (see Table 3).

c/ $\overline{X}$ temp. = mean water temperature (°C).

Table 5.--Seawater (SW) survival information for the yearling baseline serial entry control groups (from Appendix C).

Test group[a]	Survival[b/c]		
	30 days SW (%)	60 days SW (%)	90 days SW (%)
1	90.0	88.7	82.7
2	94.0	90.7	86.0
3	97.3	97.3	93.3
4	100.0	100.0	94.0
5	93.3	92.0	91.3
6	99.3	98.7	90.7
7	96.0	93.3	93.3
8	92.7	83.3	65.3

a/ 1 - 8 indicates successive serial entry groups.

b/ All groups intraperitoneally vaccinated with a bivalent *Vibrio* vaccine (Harrell et al. 1976) prior to seawater entry.

c/ Survival comparisons are only considered to 90 days seawater because: (1) after this period some of the serially entered groups were exposed to warm water and disease outbreaks and (2) the effectiveness of *Vibrio* vaccine reduces after about 90 days.

Table 6.--Biochemical information pertaining to smoltification for the yearling baseline coho salmon serial entry groups (from Appendix E).

Test group[a/]	Sample date[b/]	$\bar{X}$ FW ATPase[c/]	$\bar{X}$ FW plasma T_4[d/]
1	12 March 1979	9.3 ±2.3	11.7 ±1.5
2	26 March 1979	11.5 ±3.0	23.7 ±1.1
3	9 April 1979	18.0 ±3.5	31.9 ±2.1
4	23 April 1979	27.0 ±5.6	39.2 ±2.9
5	7 May 1979	17.0 ±2.5	22.4 ±1.1
6	23 May 1979	8.9 ±1.2	25.5 ±1.1
7	6 June 1979	5.6 ±1.8	17.9 ±1.7
8	9 July 1979	4.9 ±1.6	21.9 ±2.3

a/ 1 - 8 indicates successive serial entry groups.

b/ Samples taken in fresh water, about 1 week before seawater entry.

c/ $\bar{X}$ FW ATPase = mean freshwater gill Na^+-K^+ ATPase activity (μmoles $P_i \cdot mg\ Prot.^{-1} \cdot hr^{-1}$, ± one standard deviation.

d/ $\bar{X}$ FW plasma T_4 = mean plasma T_4 concentration (ng/ml) ± one standard deviation.

Table 7.--Statistical evaluation of changes in swimming stamina (U-critical) between testing periods for the yearling baseline coho salmon serial entry test groups.

	Entry group[a]							
Test period[b]	1	2	3	4	5	6	7	8
FW through 3SW[c]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
FW vs 1SW[d]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	ns
1SW vs 2SW[d]	ns	0.01	0.01	ns	0.05	0.05	0.01	0.01
2SW vs 3SW[d]	ns	0.05	ns	ns	0.01	ns	ns	ns
FW vs 3SW[d]	ns	ns	ns	ns	ns	ns	ns	ns
FW vs 2SW[d]	0.01	0.01	ns	0.01	0.01	0.01	ns	ns
1SW vs 3SW[d]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05

a/ 1 - 8 indicates successive serial entry test groups, n = 20 to 40 at each testing period (Table 3).

b/ FW = freshwater testing period, 1SW = first week seawater testing period, 2SW = second week seawater testing period, 3SW = third week seawater testing period, ns = no significant difference.

c/ Differences in mean swimming stamina between all four testing periods evaluated by single classification ANOVA, ($\alpha \leq 0.05$).

d/ Comparisons of mean swimming stamina between individual testing periods evaluated by Scheffe's test for multiple contrast comparisons, ($\alpha \leq 0.05$).

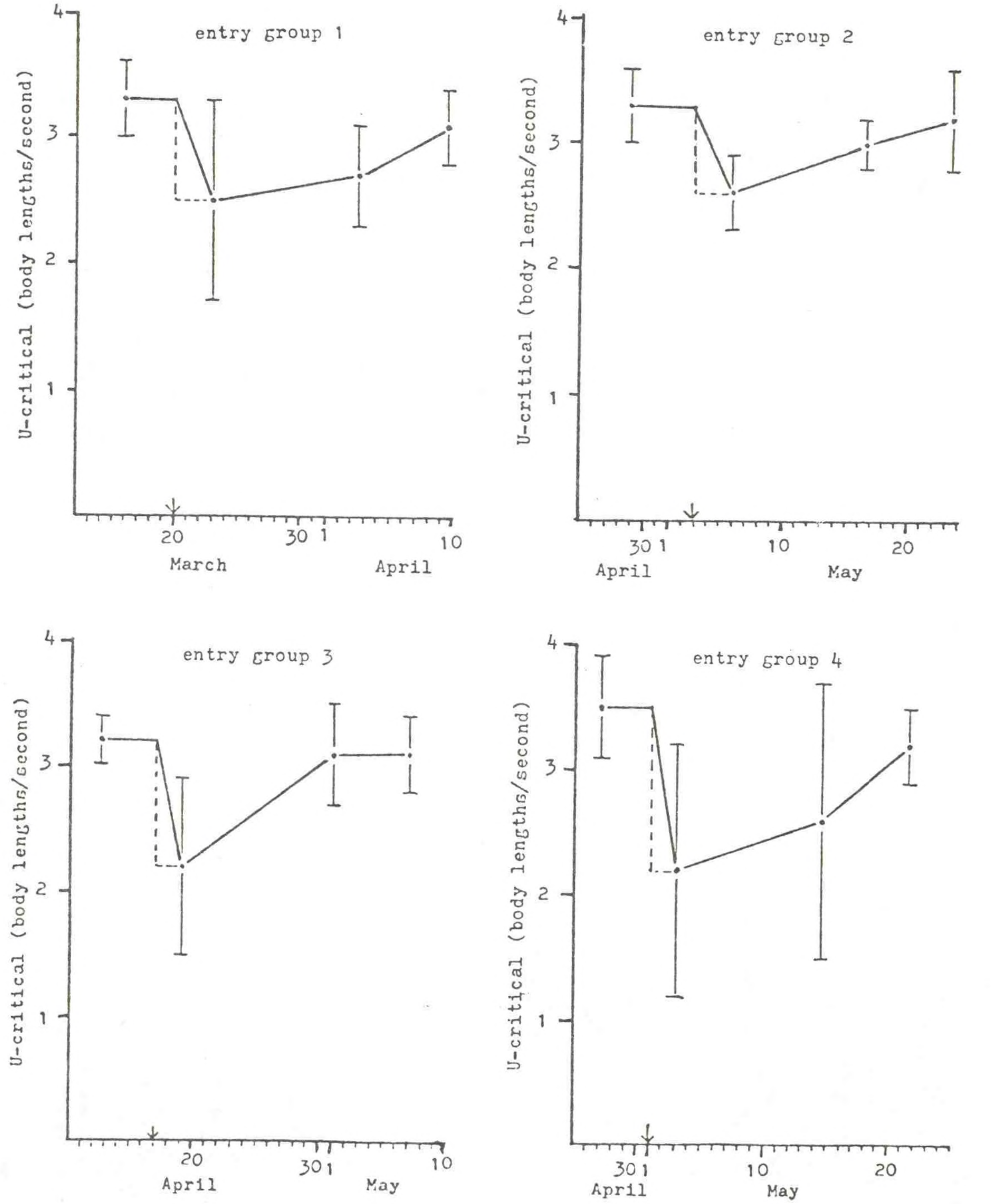


Figure 2. Changes in swimming stamina (U-critical) for the yearling baseline coho salmon serial entry test groups. Brackets indicate ± one standard deviation. Arrows indicate seawater entry date. Dashes indicate probable decrease in U-critical coinciding with seawater transfer.

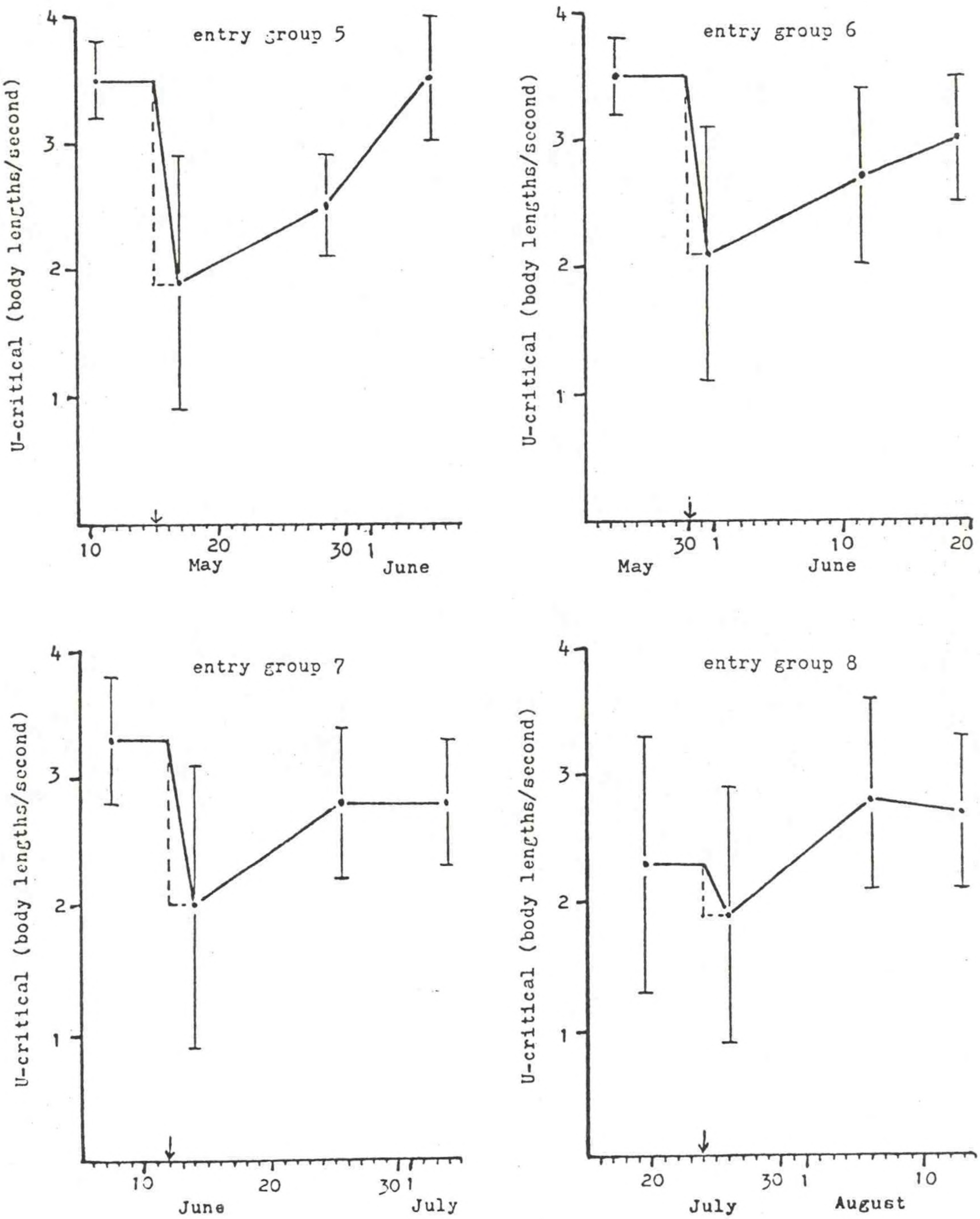


Figure 2. Continued.

Table 8.--Statistical evaluation of variations in swimming stamina (U-critical) during individual testing periods for the yearling baseline coho salmon serial entry test groups.

	Entry group[a/]							
Test period[b/]	1-8[c/]	1 vs 2[d/]	2 vs 3[d/]	3 vs 4[d/]	4 vs 5[d/]	5 vs 6[d/]	6 vs 7[d/]	6 vs 8[d/]
FW	0.01	ns	ns	ns	ns	ns	ns	0.01
1st week SW	ns	ns	ns	ns	ns	ns	ns	ns
2nd week SW	0.01	ns	ns	0.01	ns	ns	ns	ns
3rd week SW	0.01	ns	ns	ns	ns	0.05	ns	ns

a/ 1 -8 indicates successive serial entry test groups, n = 20 to 40 at each testing period (see Table 3).

b/ FW = fresh water, SW = seawater, ns = no significant difference.

c/ Differences in mean swimming stamina between all eight test groups during each individual testing period evaluated by single classification ANOVA, ($\alpha \leq 0.05$).

d/ Comparisons of mean swimming stamina between individual test groups evaluated by Scheffe's test for multiple contrast comparisons, ($\alpha \leq 0.05$).

(Table 8 and Figure 3). This group was compromised by a combination of high water temperatures and disease prior to the freshwater testing period and had a slight, but not significant, depression in swimming stamina at seawater entry (Table 7 and Figure 2).

All eight groups had statistically ($\alpha = 0.01$) the same swimming stamina level during the first week of seawater residence (Table 8). The initial reductions in swimming stamina were followed by progressive increases to the freshwater level. In all cases the return to a freshwater swimming stamina level required from 2 to 3 weeks (Table 7 and Figure 2). Similar recovery periods have also been noted in previous studies of both 0-age and yearling coho salmon (Flagg and Smith 1979).

Adjustment to a hyper-osmotic medium requires that salmonids make major osmotic shifts. Initially there are important anionic (Cl^-) and cationic (Na^+, Mg^{++}) imbalances which re-equilibrate as the fish adjust to the saline environment (Conte et al. 1966; Miles and Smith 1968; Clarke and Blackburn 1977; Clarke and Blackburn 1978; Folmar et al. 1979). There are also imbalances in several major hormonal and enzymatic systems, for example, plasma thyroxine and gill Na^+-K^+ ATPase, which occur with entry to seawater (Lasserre et al. 1978; Folmar 1979; Folmar and Dickhoff 1979). The reductions in swimming stamina associated with direct seawater entry are, apparently, the result of these complex biochemical changes and the recovery to the freshwater swimming stamina level is believed indicative of adjustment to the saline environment. It is assumed that the major stress at seawater entry is associated with the ionic imbalances which stabilize within the first 24 to 40 hours (Conte et al. 1966; Miles and Smith 1968; Clarke and Blackburn 1977; Clarke and Blackburn 1978). In

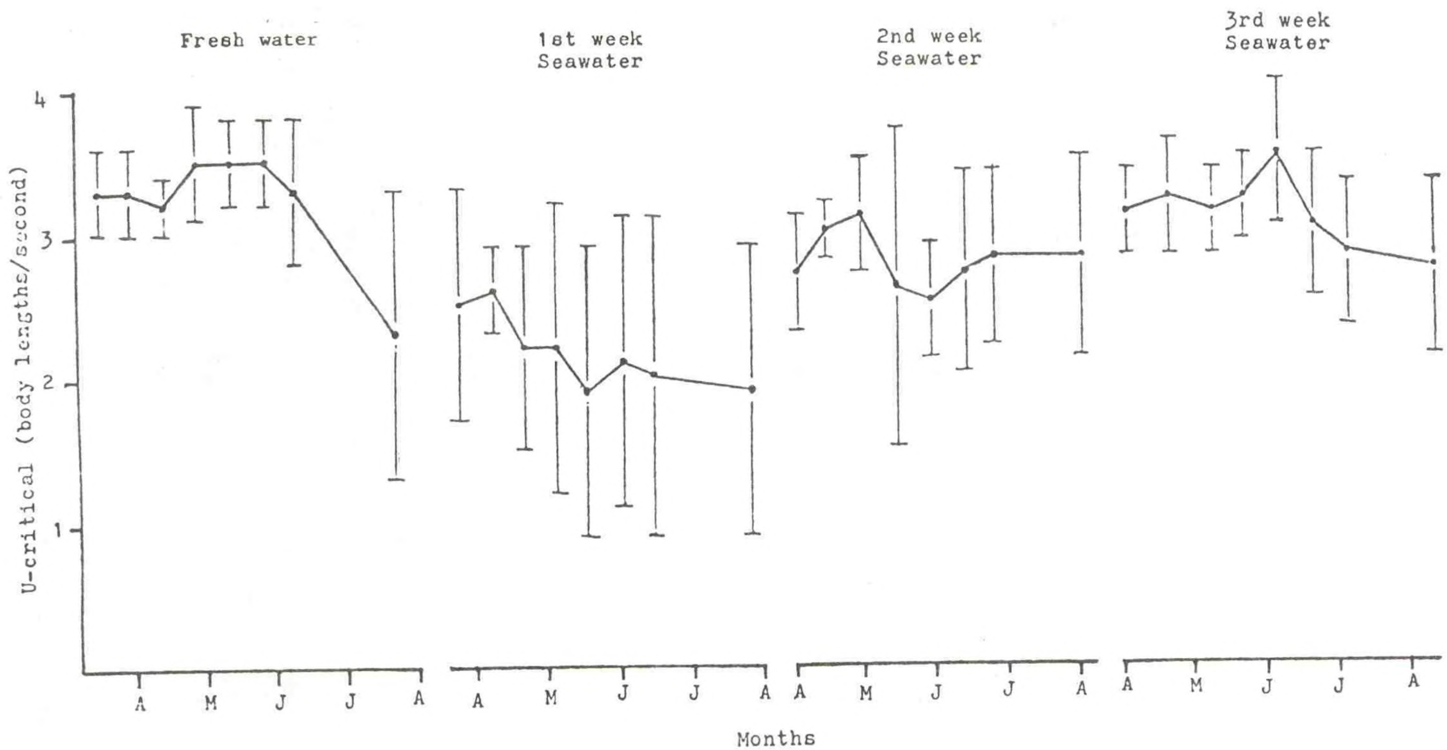


Figure 3. Variations in swimming stamina (U-critical) at the individual testing periods for the yearling baseline coho salmon serial entry test groups. Points indicate successive serial entry test groups. Brackets indicate ± one standard deviation.

the present study, the 2- to 3-week period for total swimming stamina recovery after seawater entry suggests a much longer seawater adjustive phase than was previously recognized. These data invite further investigation of the biochemical imbalances that occur with transfer to seawater.

It is generally accepted that for salmonids, an important relationship may exist between smoltification status and successful seawater survival (Hoar 1976; Folmar 1979). The changes in swimming stamina documented in the present study were not related to either the entry groups' status of smoltification, as determined by freshwater profiles of gill Na^{+}-K^{+} ATPase and plasma thyroxine (Figures 4 and 5) or their survival to 90 days in seawater (Table 9). Other studies of coho salmon have indicated that the changes in swimming stamina associated with direct seawater entry may be correlated to the status of smoltification. Those studies noted that no significant reductions in swimming stamina were experienced when seawater transfer coincided with the apparent optimal smolt entry period (Flagg and Smith 1979; Besner 1980). It is possible that there is a short period coinciding with the optimal period of smoltification that enables coho salmon to enter seawater without experiencing reductions in swimming stamina. Even so, the present study indicates that in most cases direct seawater transfer will have an initial debilitating effect on coho salmon.

Severe stress (such as swimming fatigue) induces complex metabolic disturbances which can cause long-term physiological dysfunctions or even death (Wedemeyer 1976; Mazeaud et al. 1977). No immediate deaths could be attributed to swimming fatigue in either fresh water or seawater. Delayed mortalities did, however, result after the seawater swimming fatigue tests (Table 3). During the first week of seawater residence swimming fatigue caused significant mortalities in all eight test groups, thereafter

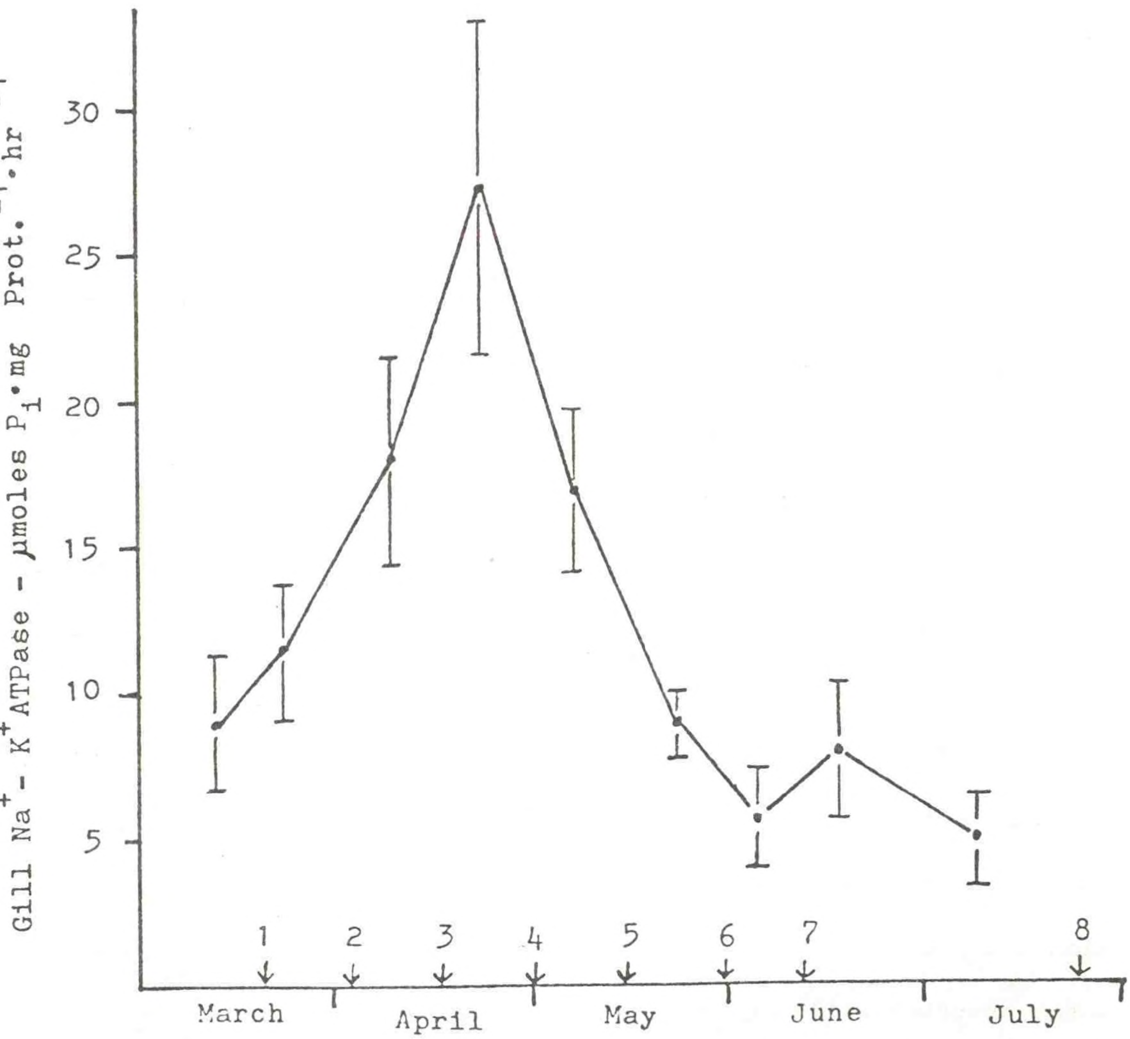


Figure 4. Mean freshwater gill Na^{+}-K^{+}ATPase activity for the yearling baseline coho salmon serial entry groups. Arrows indicate successive entry dates for test entries 1 through 8. Brackets indicate ± one standard deviation.

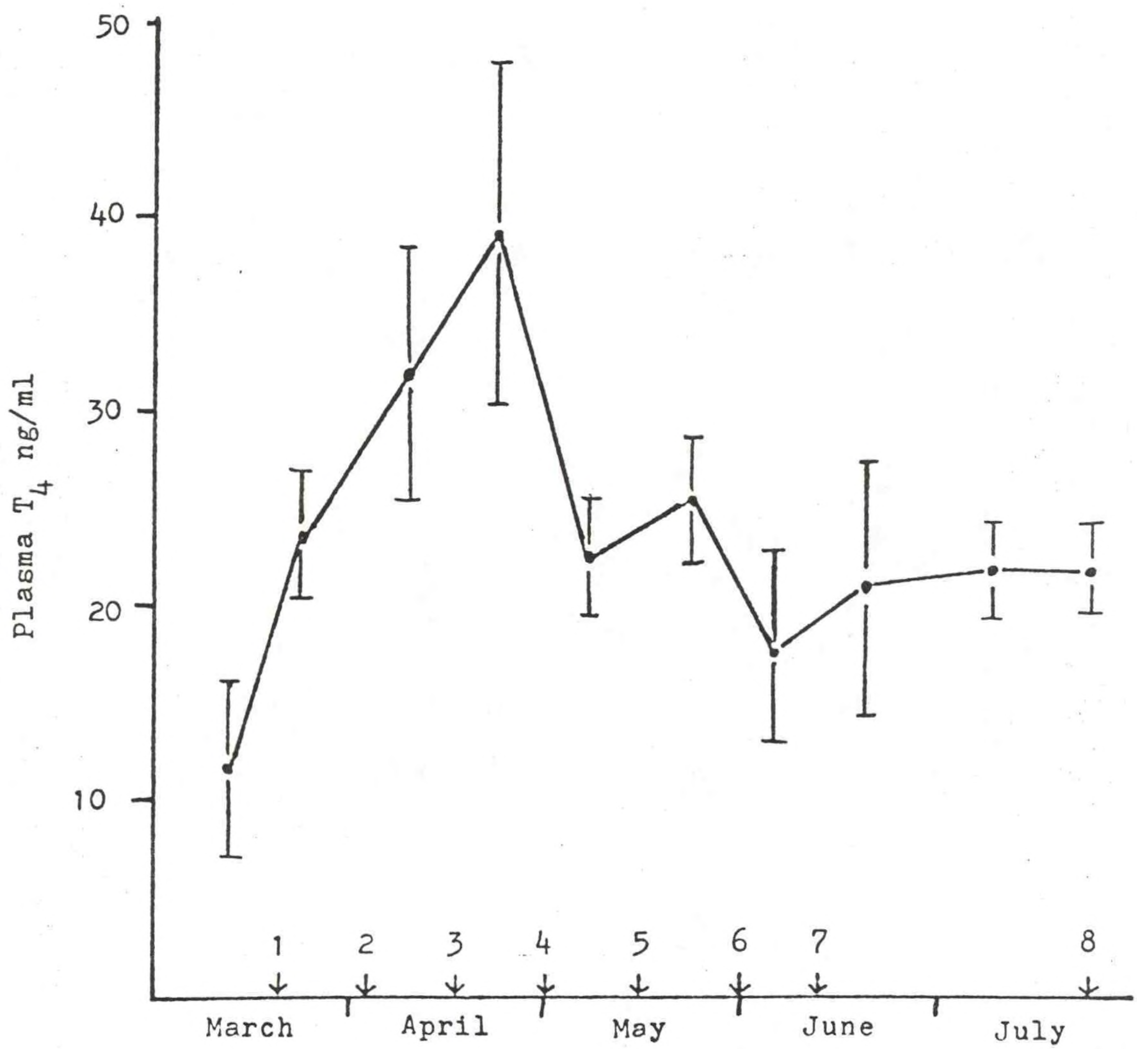


Figure 5. Mean freshwater plasma thyroxine (T_4) concentrations for the yearling baseline coho salmon serial entry groups. Arrows indicate successive entry dates for test entries 1 through 8. Brackets indicate ± one standard deviation.

Table 9.--Statistical relationships between swimming stamina (U-critical), swimming fatigue survival to 7-day post-test, control survival to 7-day post-test, and the freshwater biochemical indicators of smoltification status and survival to 30, 60, and 90 days post-seawater entry for the yearling baseline coho salmon serial entry groups.

Test parameter a/	U-critical b/				Fatigue survival b/			
	FW	1SW	2SW	3SW	FW	1SW	2SW	3SW
U-crit FW	--	ns	ns	ns	c/	ns	ns	ns
U-crit 1SW	ns	--	ns	ns	ns	ns	ns	ns
U-crit 2SW	ns	ns	--	ns	ns	ns	ns	ns
U-crit 3SW	ns	ns	ns	--	ns	ns	ns	ns
FW fatigue survival	c/	ns	ns	ns	--	ns	ns	ns
1SW fatigue survival	ns	ns	ns	ns	ns	--	ns	ns
2SW fatigue survival	ns	ns	ns	ns	ns	ns	--	ns
3SW fatigue survival	ns	ns	ns	ns	ns	ns	ns	--
7-day control survival	c/	ns	ns	ns	c/	ns	ns	ns
30-day SW survival	ns	ns	ns	ns	ns	ns	ns	ns
60-day SW survival	d/	ns	ns	ns	ns	ns	ns	ns
90-day SW survival	d/	ns	ns	ns	ns	ns	ns	ns
FW Na^+-K^+ ATPase	ns	ns	ns	ns	ns	0.02	ns	ns
FW plasma T_4	ns	ns	ns	ns	ns	0.01	ns	ns
Length	ns	ns	ns	ns	ns	ns	ns	ns
Temperature	ns	ns	ns	ns	ns	ns	ns	ns

a/ FW = fresh water, SW = seawater, 1SW = first week seawater testing period, 2SW = second week seawater testing period, 3SW = third week seawater testing period, U-crit = U-critical, FW Na^+-K^+ ATPASE = mean gill Na^+-K^+ ATPase activity about 1 week prior to seawater entry, FW plasma T_4 = mean plasma T_4 concentration about 1 week prior to seawater entry, ns = no significant relationship.

b/ All items tested by the Pearson's Product Moment Test of Correlation n=8, ($\alpha \leq 0.05$).

c/ Test invalid due to equipment failure causing mortalities.

d/ Test statistically invalid due to outlier group (entry group 8) having high water temperature and disease problems.

swimming fatigue was usually not a lethal stress (Table 3 and Figure 6). Most necroposied fish showed no pathogens (Table 10). Therefore, it is assumed that osmoregulatory dysfunction was a contributing factor in these mortalities.

There were no significant correlations between the swimming stamina levels of the entry groups and their ability to survive swimming fatigue (Table 9). Also, there were no significant relationships between the ability of the fish to survive swimming fatigue and control survival to 90 days in seawater (Table 9). Additionally, there were no significant relationships between the mean length of the fish or the mean water temperature during testing and either the swimming stamina of the fish or their ability to survive swimming fatigue (Tables 4 and 9).

The seasonal increases in gill Na^{+}-K^{+} ATPase activity and plasma thyroxine (T_4) concentrations are generally considered to be important components in the preparatory mechanisms that enable adequate osmoregulation at the time of seawater entry and, therefore, potentially related to the overall seawater adaptability and survival of the fish (Zaugg and McLain 1972; Zaugg and Wagner 1973; Hoar 1976; Lasserre et al. 1978; Dickhoff et al. 1978; Folmar 1979). At transfer to seawater, the ability of the fish to survive swimming fatigue was significantly correlated to both freshwater gill Na^{+}-K^{+} ATPase activity (α = 0.02) and freshwater plasma thyroxine (T_4) concentrations (α = 0.01) (Table 10 and Figures 7 and 8).

In the present study, the ability of the fish to survive swimming fatigue at transfer to seawater progressively increased as the entry groups approached the peak of smoltification (based on visual and biochemical

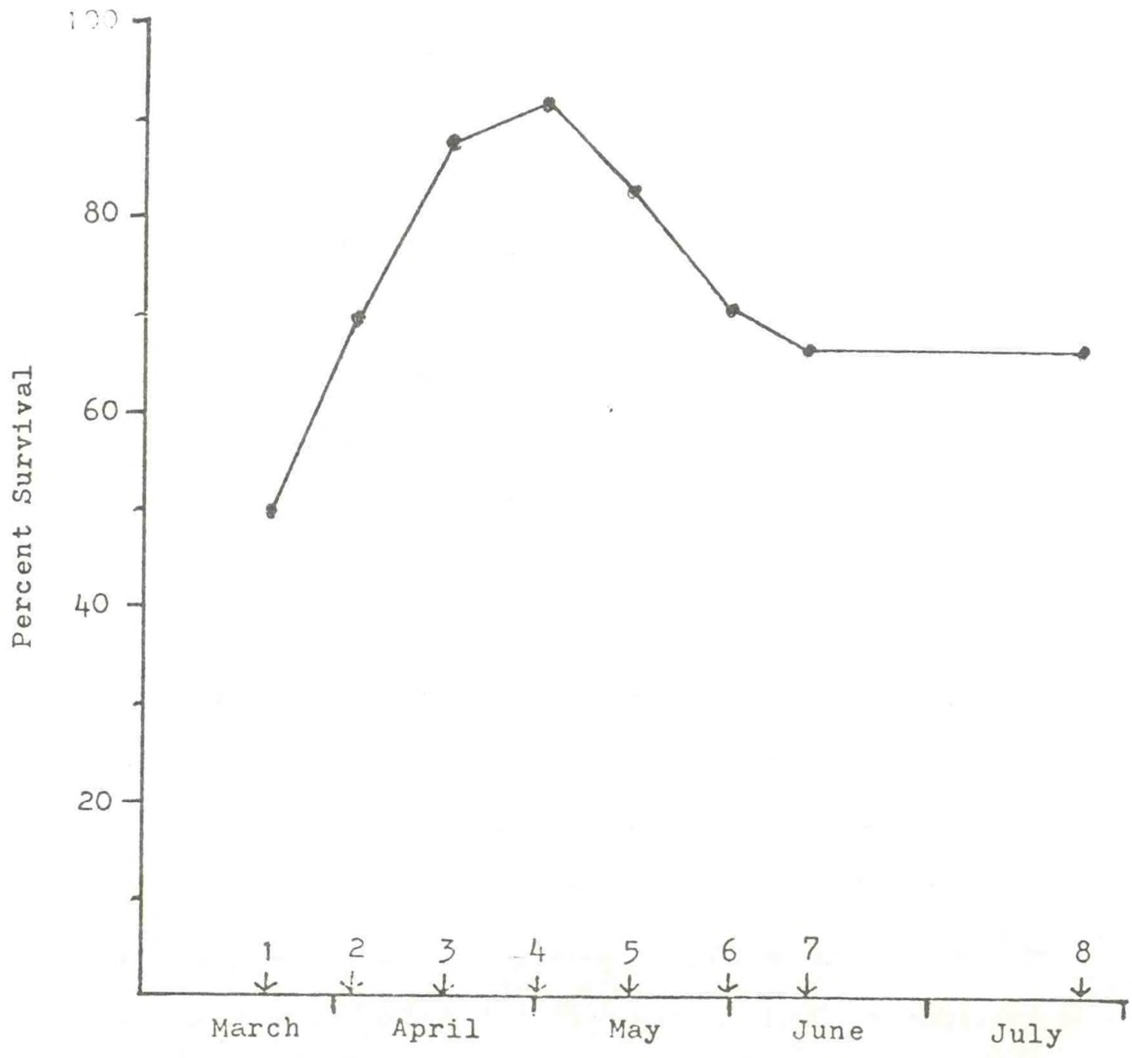


Figure 6. First week seawater swimming fatigue survival after 7 days of post-test holding for yearling baseline coho salmon serial entry test groups. Arrows indicate successive entry dates for test entries 1 through 8.

Table 10.--Inventory record and pathologist's diagnosis of delayed mortalities from swimming fatigue tests during the first week of seawater residence for the baseline coho serial entry groups.

INVENTORY RECORD

Test[a/] group	Fish held for delayed mortality (No.)	Fish alive at termination (No.)	Survival (%)	Mortalities examined (No.)
1	32	16	50.0	0
2	24	17	70.8	3
3	24	21	87.5	2
4	24	22	91.7	1
5	24	20	83.3	1
6	24	17	70.8	3
7	24	16	66.6	3
8	24	16	66.6	0

PATHOLOGIST'S DIAGNOSIS OF MORTALITIES EXAMINED

Test[a/] group	Negative[b/]	BKD[c/]	Vibrio spp.[d/]	ERM[e/]	Aero liq[f/]	Furun[g/]
2	2	0	1	0	0	0
3	2	0	0	0	0	0
4	1	0	0	0	0	0
5	1	0	0	0	0	0
6	2	0	1	0	0	0
7	1	0	2	0	0	0

a/ 1 - 8 indicates successive serial entry groups

b/ no pathogens diagnosed

c/ Bacterial Kidney Disease

d/ *Vibrio anguillarum* species

e/ Enteric Red Mouth

f/ *Aeromonas liquefaciens*

g/ Furunculosis

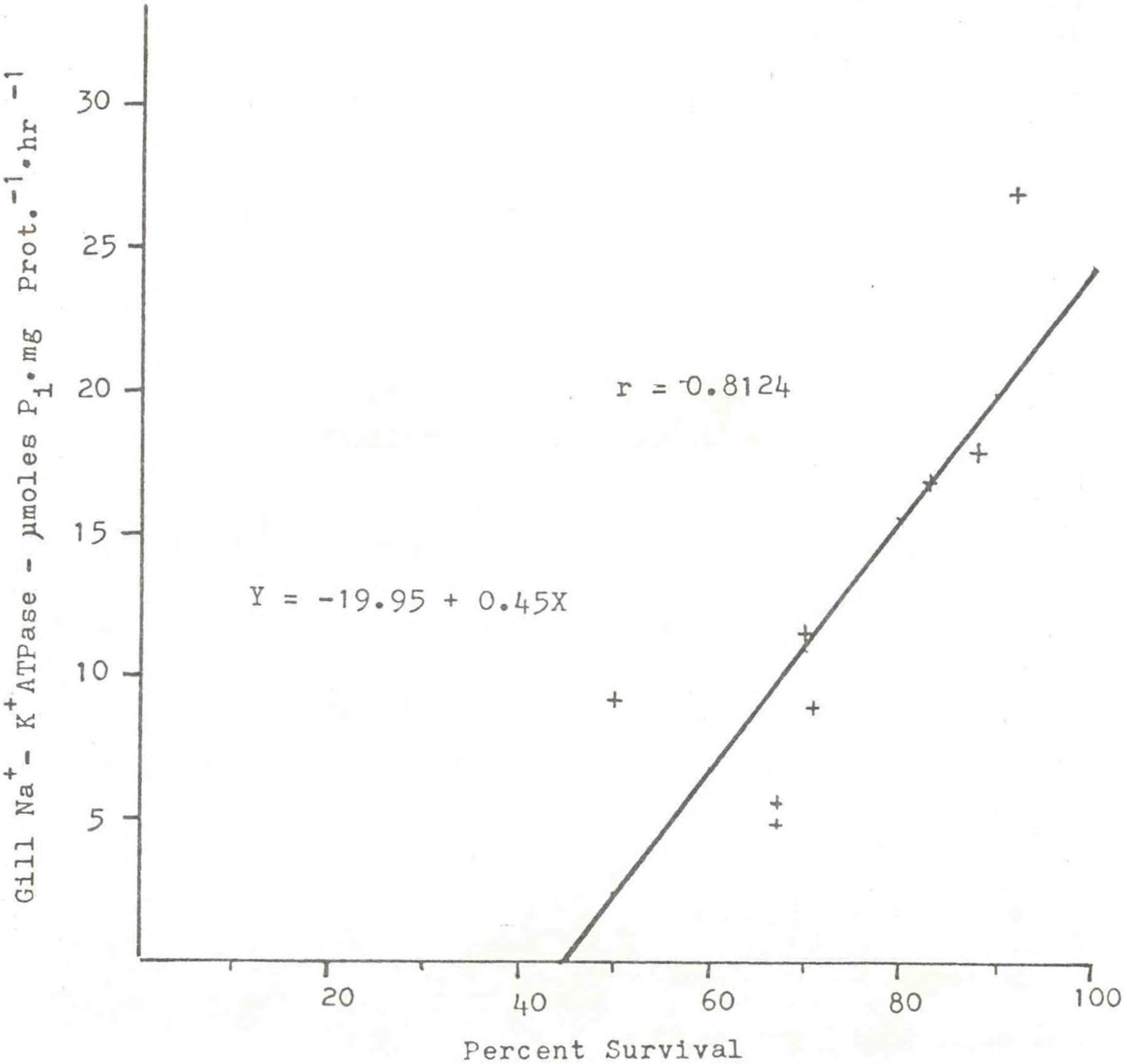


Figure 7. A linear regression analysis of percent swimming fatigue survival (7-day) for the yearling baseline coho salmon serial entry test groups fatigued during their first week of seawater residence vs their mean gill Na^+-K^+ ATPase activity in fresh water.

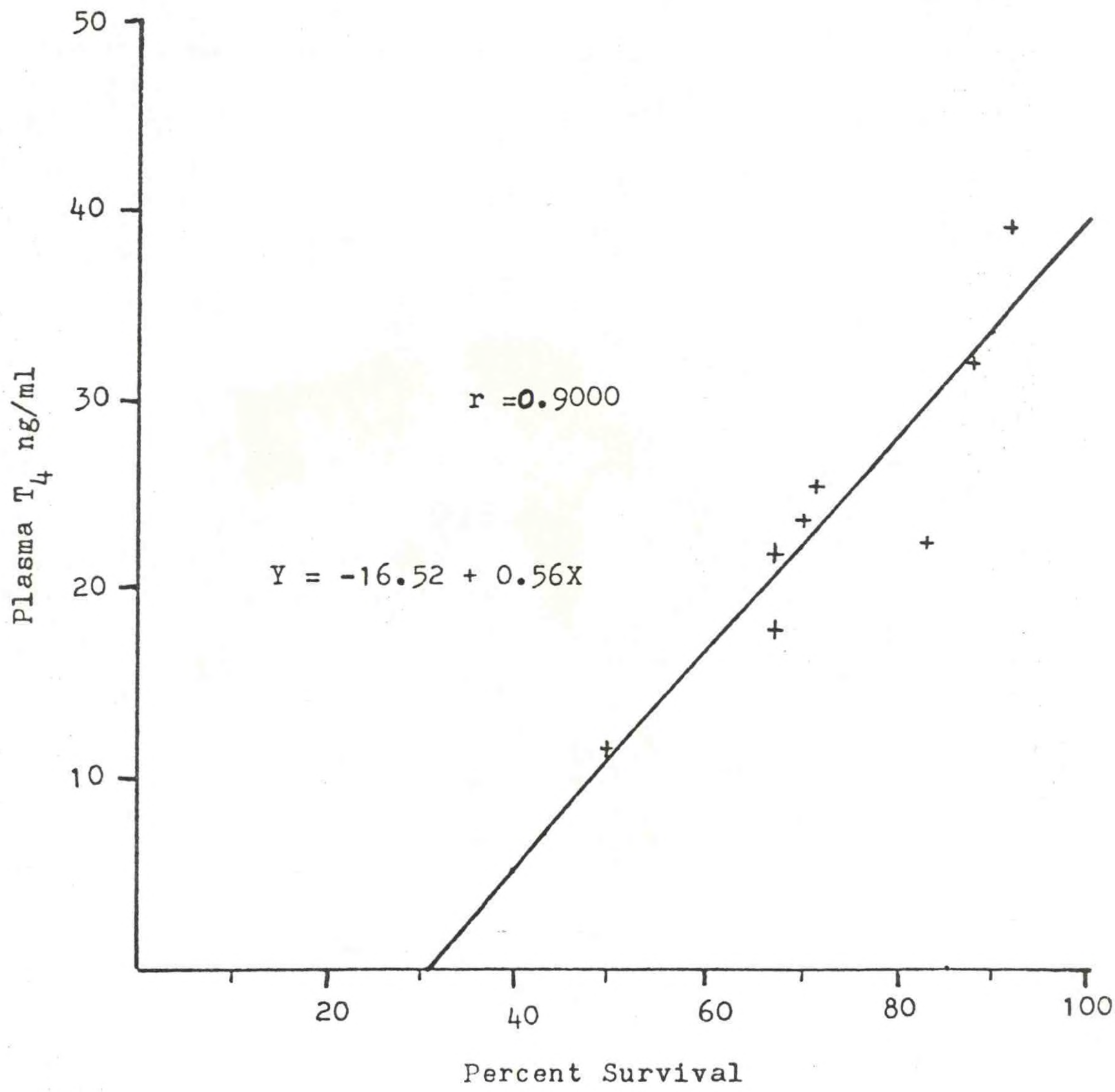


Figure 8. A linear regression analysis of percent swimming fatigue survival (7-day) for the yearling baseline coho salmon serial entry test groups fatigued during their first week of seawater residence vs their mean plasma thyroxine (T_4) concentrations in fresh water.

indicators), and this ability declined thereafter (Figure 6). These data suggest that adequate osmoregulatory pre-adaption is a major factor in coping with stress during adjustment to seawater. The present study indicates that, for coho salmon, the maximum ability to survive stress (such as swimming fatigue) at seawater entry is attained in conjunction with the freshwater developmental peaks of both plasma thyroxine (T_4) and gill Na^+-K^+ ATPase. The evidence suggests that proper assessment of the status of smoltification is essential to attaining maximum seawater survival for coho salmon.

LITERATURE CITED

Baggerman, B.
1960. Salinity preference, thyroid activity and seaward migration of four species of Pacific salmon (Oncorhynchus). J. Fish. Res. Board Can. 17:295-322.

Beamish, F. W. H.
1978. Swimming capacity. IN W. S. Hoar and D. J. Randall - editors. Fish Physiology, Vol. VII. Academic Press Inc. New York, p. 135.

Bell, W. H. and L. D. Terhune.
1970. Water tunnel design for fisheries research. Fish Res. Board Can., Tech. Rpt. No. 195, p. 56.

Besner, M.
1980. Endurance Training: An affordable strategy to increase food conversion efficiency, stamina, growth and survival of coho salmon smolts (Oncorhynchus kisutch). PhD. Thesis, Univ. of Washington, 177 pp.

Clarke, W. C., and J. Blackburn.
1977. A seawater challenge test to measure smolting in juvenile salmon. Dept. Environ. Fish. Mar. Serv. Res. Div. Dir., Tech. Rpt. No. 705, 11 pp.

Clarke, W. C., and J. Blackburn.
1978. Seawater challenge tests performed on hatchery stocks of chinook and coho salmon in 1977. Fish. Mar. Serv. Tech. Rep. 761: 19 p.

Clarke, W. C., and Y. Nagahama.
1977. The effects of premature transfer to seawater on growth and morphology of the pituitary, thyroid, pancreas, and interrenal in juvenile coho salmon (Oncorhynchus kisutch). Can. J. Zool. 55:1620-1630.

Conte, F. P., H. H. Wagner, J. C. Fessler and C. Gnose.
1966. Development of osmotic and ionic regulation in juvenile coho salmon (Oncorhynchus kisutch). Comp. Biochem. Physiol. 18:1-15.

Dickhoff, W. W., L. C. Folmar, and A. Gorbman.
1978. Changes in plasma thyroxine during smoltification of coho salmon, (Oncorhynchus kisutch). Gen. Comp. Endocr. 36, 229-232.

Flagg, T. A., and L. S. Smith.
1979. Appendix F: Changes in swimming performance, critical fatigue levels, and metabolic rates during the parr-smolt transformation of Toutle (accelerated underyearling) coho salmon (Oncorhynchus kisutch). IN FY 1978-79 report, Project 817, A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center.

Folmar, L. C.
1979. Some physiological changes in coho salmon (Oncorhynchus kisutch) during smoltification and seawater adaption. Ph. D. Thesis. Univ. of Washington. 153 pp.

Folmar, L. C., and W. W. Dickhoff.
1979. Plasma thyroxine and gill Na^{+}-K^{+} ATPase changes during seawater acclimation of coho salmon, Oncorhynchus kisutch. Comp. Biochem. Physiol., Vol. 63A. pp. 329 to 332.

Folmar, L. C., W. S. Zaugg, and W. W. Dickhoff.
1979. Appendix E: Some physiological changes in coho salmon during smoltification and seawater adaption. Unpublished manuscript, 37 p., IN FY 1978-79 report, Project 817, A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center.

Harrell, L. W., A. J. Novotny, M. H. Schiewe, and H. O. Hodgins.
1976. Isolation and description of two vibrios pathogenic to Pacific salmon in Puget Sound, Washington. NOAA, NMFS Fisheries Bulletin 72(2): p. 447-449.

Hoar, W. S.
1976. Smolt transformation: evolution, behavior, and physiology. J. Fish. Res. Board. Can. 33:1233-1252.

Houston, A. H.
1957. Responses of juvenile chum, pink, and coho salmon to sharp sea-water gradients. Can. J. Zool. 35:371-383.

Houston, A. H.
1959. Locomotor performance of chum salmon fry (Oncorhynchus keta) during osmoregulation to sea water. Can. J. Zool. 37:591-604.

Huntsman, A. G., and W. S. Hoar.
1939. Resistance of Atlantic salmon to sea water. J. Fish. Res. Board Can. 4:409-411.

Lasserre, P., G. Boeuf, and Y. Harache.
1978. Osmotic adaption of Oncorhynchus kisutch Walbaum I. Seasonal variations of gill Na^{+}-K^{+} ATPase activity in coho salmon, 0^{+}-age and yearling, reared in fresh water. Aquaculture, 14:365-382.

Mazeaud, M. M., F. Mazeaud, and E. M. Donaldson.
1977. Primary and secondary effects of stress in fish: some new data with a general review. Trans. Amer. Fish. Soc., 106(3):201-212.

Miles, H. M., and L. S. Smith.
1968. Ionic regulation in migrating juvenile coho salmon (Oncorhynchus kisutch). Comp. Biochem. Physiol., 26:381-398.

Prentice, E. F., F. W. Waknitz, and K. X. Gores.
1979. Appendix B: Saltwater adaption of coho salmon, spring and fall chinook salmon, and steelhead. Unpublished manuscript, 192 p., IN FY 1978-79 report, Project 817, A study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead. Coastal Zone and Estuarine Studies Division, Northwest and Alaska Fisheries Center.

Sokal, R. R., and F. J. Rohlf.
1969. Biometry. W. H. Freeman Co., San Francisco. 776 pp.

Smith, L. S., and T. W. Newcomb.
1970. A modified version of the Blaska respirometer and exercise chamber for large fish. J. Fish. Res. Board. Can. 27:1321-1324.

Wedemeyer, G. A.
1976. Physiological responses of juvenile coho salmon (Oncorhynchus kisutch) and rainbow trout (Salmo gairdneri) to handling and crowding stress in intensive fish culture. J. Fish. Res. Board Can. 33:2699-2702.

Woo, N. Y. S., H. H. Burns and R. S. Nishioka.
1978. Changes in body composition associated with smoltification and premature transfer to seawater in coho (Oncorhynchus kisutch) and king salmon (Oncorhynchus tshawytscha). J. Fish. Biol. 13:421-428.

Zaugg, W. S., and L. R. McLain
1972. Changes in gill adenosine-triphosphatase activity associated with parr-smolt transformation in steelhead trout, coho, and spring chinook salmon. J. Fish. Res. Board Can. 29:161-171.

Zaugg, W. S., and H. H. Wagner.
1973. Gill ATPase activity related to parr-smolt transformation and migration in steelhead trout (Salmo gairdneri): Influence of photo period and temperature. Comp. Biochem. Physiol. 45:955-965.