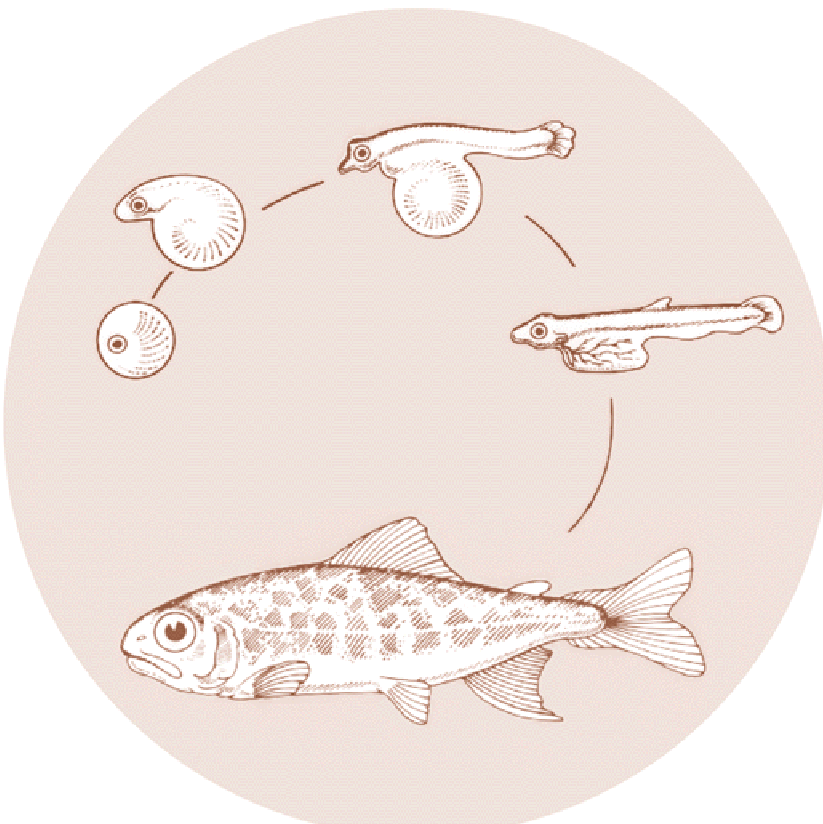
September 1994

WILLAMETTE OXYGEN SUPPLEMENTATION STUDIES

Annual Progress Report



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Please include title, author, and DOE/BP number in the request.

WILLAMETTE OXYGEN SUPPLEMENTATION STUDIES

Annual Progress Report

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Project No. 88-160
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September 1994

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Appendices containing information from the continuous monitoring system are provided with accompanying floppy disks.

INTRODUCTION

Hydropower development and operations in the Columbia River basin have caused the loss of 5 million to 11 million salmonids. . An interim goal of the Northwest Power Planning Council is to reestablish these historical numbers by doubling the present runs from 2.5 million adult fish to 5.0 million adult fish. This increase in production will be accomplished through comprehensive management of both wild and hatchery fish, but'artificial propagation will play a major role in the augmentation process. The current husbandry techniques in existing hatcheries require improvements that may include changes in rearing densities, addition of oxygen, removal of excess nitrogen, and improvement in raceway design. Emphasis will be placed on the ability to increase the number. of fish released from hatcheries that survive to return as adults.

Rearing density is one of the most important elements in fish'culture. Fish culturists have attempted to rear fish in hatchery ponds at densities that most efficiently use the rearing space available. Such efficiency studies require a knowledge of cost of rearing and the return of'adults to the fisheriesand to' the hatchery.

It is widely accepted that the limitations on survival imposed by rearing densities are. dependent upon oxygen availability. The models of Westers (1970), Liao (1971), and

Banks et al. (1979) are based on the limitations of oxygen availability at various densities, temperature, and sizes of the fish being reared. In the past oxygen limitations has been overcome by increased flow, but in recent years, addition-of oxygen to the raceways has become an acceptable alternative.

In spite of the acceptance of oxygen as the limiting factor in fish culture at the present time, there has been little information on the relationship between oxygen availability to cultured salmon and their subseguent survival to adulthood after release. This project will extend that information by examining the effects of oxygen supplementation in a surface water hatchery on the rearing and surival of spring chinook salmon. The first four years of the project will look at the operational aspects of the use of oxygen, the effects on water guality on oxygen utilization, and overall quality of fish reared at high densities with supplemental oxygen. Results from the start up and three years of releases have already been described (Ewing and Sheahan 1990; Ewing and Sheahan 1991; Ewing and Sheahan 1992; Ewing et. al. 1993).

METHODS AND MATERIALS

Fish Culture

Spring chinook salmon (Oncorhynchus tshawytschal adults were collected at the Dexter holding ponds below the Dexter Dam, 15 miles east of Eugene. The adults were hauled to Willamette' Hatchery in Oakridge, Oregon, and were held in a 300 foot long by 15 feet wide excavated rock and earth pond supplied with water from Salmon Creek at a flow of about 10,600 liters per minute. Approximately 1600 adults were held throughout the summer. Spawning occurred from September through October and each egg-take was incubated separately. Juveniles released in the fall of their first year came from the earliest egg-takes. The fish used for this project were derived from,later spawnings in order not to exceed the size desired at release. These fish were ponded in groups by hatching dates. ,

Juvenile fish were taken randomly from different egg-take groups and marked with adipose-finclips and coded-wire tags. At the time of tagging (from 6 July 1993 to, 27 July 1993) they were introduced into experimental raceways. Because of the complexity of the experimental design, the letters A through G are used to designate the different test groups (Table′1). Subscripts represent replicates. Ideal conditions\ for each raceway are given in Table 2.

When required, oxygen was added to the raceways through sealed contact columns (Westers et. al., 1988). Modifications of

Table I. Designations and pond number for experimental ponds at Willamette Hatchery.

Designation	Pond	Characteristics
A_1	7	Normal density, no oxygen supplementation
A_2	17	Replicate
B_1	6	Half density, no oxygen supplementation
B_2	16	Replicate
C_1	8	Normal density, oxygen supplementation
C_2	18	Replicate
D_1	9	Triple density, oxygen supplementation
D_2	19	Replicate
E_1	30N	Michigan system, first pass, oxygen added
E_2	30S	Replicate
F_1	20N	Michigan system, second pass, oxygen added
F_2	20s	Replicate
G_1	10s	Michigan system, third pass, oxygen added
G_2	10N	Replicate

Table 2. Ideal characteristics of experimental ponds at Willamette Hatchery[a].

Group	Number of fish	Final pounds	Inflow gpm	Load pounds/gpm	Pond volume ft^3	Density pounds/ft^3
A	36,000	3,600	500	7.2	3,700	0.970
B	18,000	1,800	500	3.6	3,700	0.486
C	36,000	3,600	500	7.2	3,700	0.970
D	108,000	10,800	500	21.6	3,700	2.919
E,F,G	54,000	5,400	750	7.2	1,850	2.919

[a] Characteristics given are approximate and should be compared with experimental numbers provided in the Results section.

the design to fit site-specific requirements were determined before experimental rearing began (Fish Factory, 1990). No packing media or dispersion plates were used, in the columns. In raceways with supplemental oxygen, dissolved oxygen in the raceway effluent was maintained at 100% of saturation. Oxygen flow into the contact column was increased or decreased manually using a Brooks rotometer.

Fish were fed BioMoist Feed from Bioproducts, Inc., Warrenton, OR. Feed was weighed daily for each pond and recorded with the cumulative amount of food per pond on a daily feed sheet. Fish growth was programmed to meet production goals based on historical monthly weight gains.

Mortalities of both tagged and untagged fish were enumerated and recorded weekly for each pond when the ponds were cleaned. cumulative mortalities were used to estimate.population sizes each month.

Water temperatures were recorded on a Taylor thermograph; Precipitation was recorded by a National Oceanic and Atmospheric Administration weather observation station located at the hatchery.

'Sample counts to determine fish per pound for the single. pass systems were taken at the end of each month by crowding the fish. Variable number of sample counts were taken by hatchery personnel on most months. Grab samples were obtained from the Michigan ponds. In September, December, and February,ten sample counts were performed for each raceway (Ewing et al. 1994). In the Michigan ponds, grab samples from various compartments were taken until ten sample counts were obtained.

Growth of the fish was calculated from pond counts in three different ways (Ricker 1975):

Absolute Change = $w_2 - w_1$

Relative Change = $(w_2 - w_1)/ w_1$

Instantaneous Rate = $\log_e w_2 - \log_e w_1$

where

w_2 = The weight at the end of the time period.

w_1 = The weight at the beginning of the time period.

Food conversions were calculated from the change in biomass- of the -raceway and the amount of food fed. The'change in the biomass was calculated as:

$$\text{Delta B} = ((N_1-M)/S_2) - (N_1/S_1)$$

where

Delta B = The change in the biomass.

N_1 = The number of fish in the pond at the start.

M = The observed mortalities.

S_2 = The sample count at the end of the month in number of fish per kg.

S_1 = The sample count at the beginning of the month in number of fish per kg.

The conversion rate for that month was then calculated as:

Conversion Rate = Delta B /kg food.

Length frequencies were obtained during tagging, in early October, in mid December and in late February. Fork lengths from samples of about 200 fish were recorded.

Numbers of fish per raceway at release were calculated from measurements of fish per pound and the total pounds of fish in a raceway. Total pounds of fish in a raceway were determined from water displacement when fish were loaded into liberation trucks. The numbers estimated at release were then compared'with population numbers estimated from monthly inventories.

Blood hematocrif levels were determined by standard methods in late February just before liberation.

In addition to the fish raised at Willamette Hatchery; 308,727 spring chinook salmon were reared at the Dexter holding ponds to ensure those mitigation goals for the hatchery were attained. These fish were also marked with coded wire tags and adipose fin clips. Samples for water quality analyses were taken periodically. At release, total numbers were estimated by the methods described above.

Water Chemist-

Water samples were collected weekly between 12:15 and 13:00. At that time, initial feeding of the fish was completed and one exchange of water had taken place without the presence of human activities. The water samples were taken in the same order: inflow into Group E, outflow from Group E, outflow from Group F, outflow.from Group G, outflow from Group D, outflow from Group C, outflow from Group A, outflow from Group B, inflow 'from an indoor rearing trough set up to record water temperatures. Three replicate samples were taken from the inflow to determine alkalinity.

Dissolved gases were measured using a Common Sensing model TBO-F Total Dissolved Gas and Oxygen Monitor. Dissolved oxygen in parts per million was calculated by the following 'formulas:

$$\text{Dissolved-Oxygen (ppm)} = pO_2 * \text{beta} * 31.9988 * 1000/(760 * 22.414)$$

$$\text{where beta} = \exp(-58.3877 + (85.8079 * (100/(273.15 + {}^\circ C)) + (23.8439 * (\ln({}^\circ C + 273.15))))$$

The pH was measured at the sample site using an Orion pH meter model SA230 and an Orion combination pH electrode.

Alkalinity analysis was done by the titration method of Clesceri et al. (1989). An end point of pH 4.5 was determined potentiometrically using the Orion pH meter.

Samples of 600 ml water were filtered through Whatman 934-AH filters, dried at 103-105°C and weighed using a Cahn Electrobalance DTL balance to determine suspended solids (Clesceri et al. 1989).

Ammonia analysis was done using the phenate method (Clesceri et al. 1989). The samples and standards were read at 630 nm using a Milton Roy Spectronic 21 spectrophotometer.

A Royce System VI instrument monitoring system was installed to record the die1 changes in dissolved oxygen, temperature and pH. Dissolved oxygen probes were placed at the.inflow and outflow of ponds designated A2, B2, C2, D2, El, F1, G1. Temperature information was collected with dissolved oxygen probes. A pH probe was installed at the inflow of pond C2 to determine the pH of incoming water for pond A2, B2, C2, and D2. One probe each was placed at the outflow of ponds A2, B2, C2, and D2. In the Michigan ponds (E, F, G) a pH probe was placed at the inflow of El, inflow of F1, inflow of Gl; and outflow of G1. No differences were observed between the outflow of one pond and the inflow 'of the next pond in the series, Data was collected in 6 minute, 30 minute and'90 minute intervals and was stored as 48 hour samples, 10 day samples, and 30 days samples, respectively.

RESULTS AND DISCUSSION

Water Chemistry

Dissolved Oxygen

For comparison of the first three years of the project with this year, dissolved oxygen measurements were made weekly as described in Materials and Methods for the various experimental groups (Appendix A). Oxygen concentrations were derived from temperature and gas pressure measurements (Appendix B). Weekiy averages of dissolved oxygen concentration taken from various experimental ponds by the monitoring system are shown in Table 3. The 30 minute values for dissolved oxygen, pH and temperature are available by request and can be located in the following computer appendices:

August 1993	WIAUG93.WK1
September 1993	WISEP93.WK1
October -1993	WIOCT93.WK1
November 1993	WINOV93.WK1
December 1993	WIDEC93.WK1
January 1994	WIJAN94.WK1
February 1994	WIFEB94.WK1

Data from calibrations and malfunctioning probes have been eliminated from the spreadsheet files. Values for the incoming

Table 3. Weekly average dissolved oxygen concentrations (ppm) from the inflou (I) and outflow (O) of experimental ponds, as measured by the data monitoring system at Willamette Hatchery, 1993-94.

Date	A2		B2		C2		D2		E1		F1		G1	
	I	O	I	O	I	O	I	O	I	O	I	O	I	O
08/01/93	8.52	7.67	9.03	- -	11.10	9.04	13.50	10.18	12.75	10.90	- -	9.33	11.09	13.36
08/08/93	8.13	6.44	8.94	- -	12.15	10.66	15.10	11.92	13.18	11.24	- -	10.25	14.44	9.95
08/15/93	8.54	6.16	9.51	- -	12.63	10.12	15.29	12.63	12.60	11.15	- -	10.75	14.28	10.39
08/22/93	8.99	- -	9.23	- -	12.69	11.16	15.30	12.16	12.41	10.95	- -	10.90	14.05	10.35
08/29/93	8.68	- -	9.09	- -	12.60	9.15	14.93	10.95	12.52	10.88	- -	10.84	13.96	10.11
09/05/93	8.50	- -	9.11	- -	12.83	9.62	15.49	10.91	12.10	10.51	- -	10.99	14.91	10.37
09/12/93	9.89	- -	10.08	- -	13.77	10.75	18.43	13.43	12.52	11.24	- -	10.79	17.70	13.16
09/19/93	10.06	10.65	10.08	10.27	14.09	10.55	18.33	13.13	12.76	11.45	17.83	10.67	17.99	13.88
09/26/93	10.11	7.93	9.71	8.87	14.32	9.03	17.27	12.67	13.11	9.97	14.71	10.58	16.42	12.53
10/03/93	9.w	8.17	9.48	8.63	14.21	8.88	17.68	11.48	12.66	11.39	13.50	10.36	16.33	11.91
10/10/93	9.96	8.58	10.17	8.94	14.25	9.93	17.65	10.36	12.96	11.76	14.20	10.50	15.85	11.27
10/17/93	10.29	8.94	10.63	9.53	14.99	10.79	18.28	12.51	13.03	12.44	14.77	11.99	16.76	13.08
10/24/93	9.98	9.00	10.67	9.61	14.81	10.40	17.99	11.64	13.23	12.17	14.67	12.02	16.09	12.14
10/31/93	10.88	10.43	10.93	10.27	14.95	11.73	17.77	12.08	14.15	13.45	15.81	11.87	16.84	13.22
11/07/93	11.84	11.09	12.83	11.12	15.43	12.74	18.44	10.92	15.77	14.23	16.52	14.39	17.76	13.91
11/14/93	12.64	11.71	12.97	11.15	15.20	12.64	16.33	12.31	15.19	14.23	16.31	13.92	17.40	13.68
11/21/93	12.95	12.41	13.47	12.25	15.40	13.12	16.08	12.19	15.41	14.69	16.65	14.25	16.79	14.78
11/28/93	11.94	11.36	12.86	11.29	14.60	12.08	14.58	11.79	14.42	13.60	15.80	12.93	18.09	13.24
12/05/93	11.83	- -	11.65	11.17	14.15	10.94	14.35	10.97	13.94	14.16	14.95	12.56	16.36	12.83
12/12/93	12.28	- -	12.01	11.78	14.69	11.18	14.82	11.43	14.21	13.42	15.46	13.17	16.80	13.27
12/19/93	12.96	- -	12.89	11.94	15.50	11.94	15.65	13.10	14.76	14.20	16.18	14.47	17.54	14.71
12/26/93	11.98	- -	12.16	11.42	14.74	11.52	16.06	12.72	14.24	13.73	15.59	13.50	16.59	13.27
01/02/94	12.04	- -	12.46	11.83	14.46	11.99	15.89	10.96	14.11	13.15	15.36	13.20	16.93	13.25
01/09/94	12.45	- -	12.79	12.03	14.65	12.02	15.14	10.49	14.27	13.78	15.98	13.42	16.46	12.70
01/16/94	11.98	- -	12.14	11.50	14.29	11.36	14.70	11.46	13.91	13.29	15.34	12.65	16.23	12.25

Table 3. **Continued.**

Date	A2		B2		C2		D2		E1		F1		G1	
	I	O	I	O	I	O	I	O	I	O	I	O	I	O
01/23/94	12.85	13.73	12.12	12.11	15.24	12.15	15.76	13.74	14.34	13.68	15.85	14.35	17.39	13.45
01/30/94	13.11	12.83	13.31	12.70	15.51	11.93	16.20	13.50	14.08	13.52	15.65	14.22	17.07	12.64
02/06/94	13.10	12.08	13.05	12.38	15.50	12.64	15.90	14.32	14.74	14.50	15.44	13.74	16.67	15.32
02/13/94	12.73	11.70	12.50	12.00	15.02	12.19	15.43	13.81	14.31	14.37	15.02	12.83	15.86	13.02
02/20/94	11.75	11.13	12.13	11.68	13.58	10.91	13.68	12.19	13.23	13.33	13.44	11.10	13.37	7.78

oxygen levels for ponds F1 and G1 may be artificially elevated due to the suspended solids adhering to oxygen enriched bubbles in the contact column forming foam that can adhere to the probe. This condition was increased when the preceding pond was being fed. Correlations were observed between the decrease in dissolved oxygen at the outflow and density, load, and total number of fish per raceway (Table 4).

Table 4. Correlation coefficients (R) between the difference in oxygen between inflow and outflow for all groups and density, load, and total number of fish in the raceway. Weekly averages from the continuous monitoring system were used for the oxygen values.

Month	Density	Load	Number of fish per raceway-
Aug	0.525	0.726	0.787
Sep	0.754	0.436	0.630
Oct	0.438	0.743	0.739
Nov	0.516	0.684	0.740
Dec	0.346	0.525	0.427
Jan	0.573	0.577	0.521
Feb	0.1381	0.416	0.176

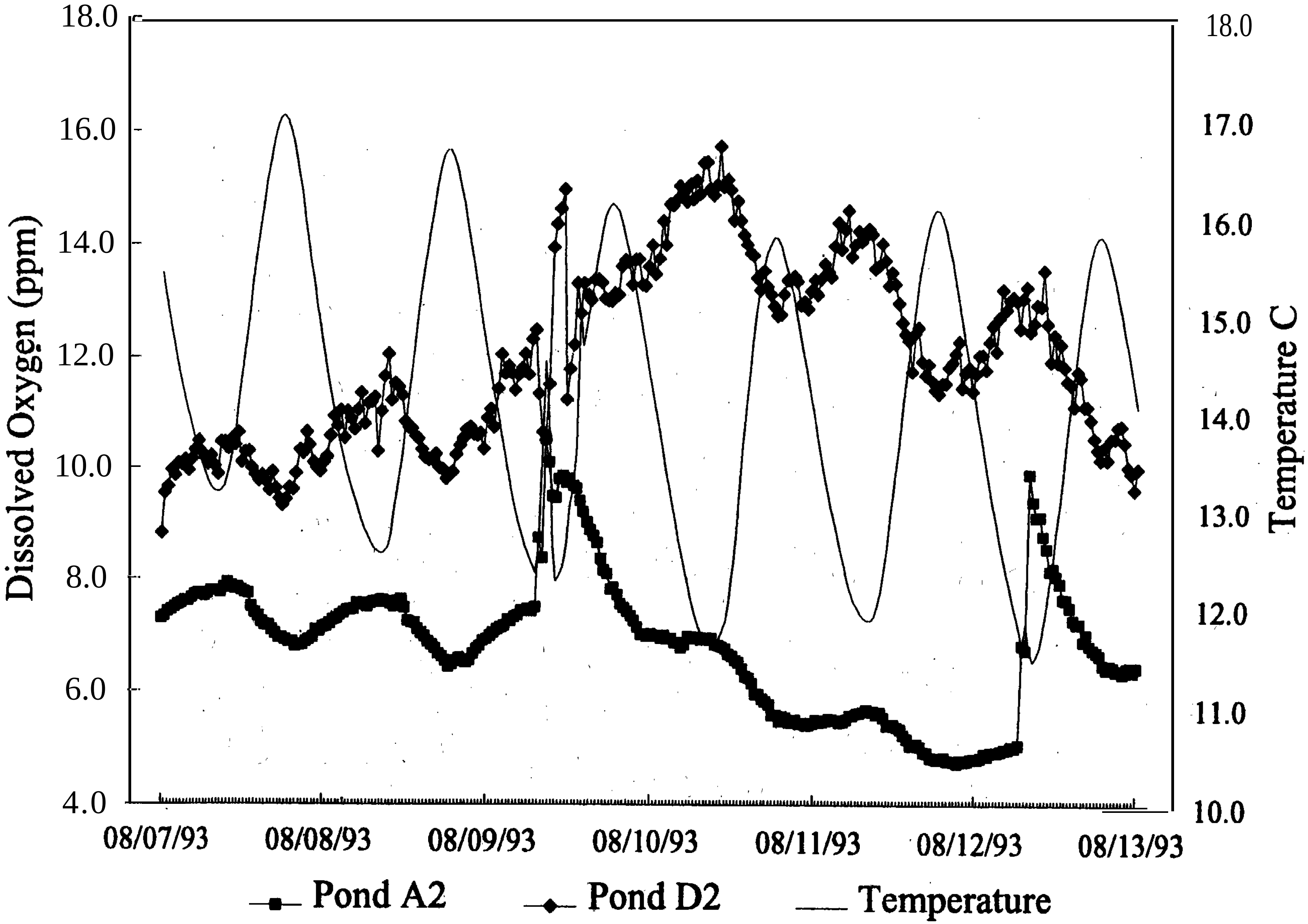
Flow of oxygen into the water supply of the various raceways was -adjusted weekly to maintain 100% saturation of-oxygen at the outflow in all groups except groups A (controls) and-group B. Adjusting the oxygen flows to provide saturated levels of oxygen at the outflow, maximum oxygen demand during the day was determined and the oxygen flow was adjusted to that level of demand.

The environment from which the oxygen samples were taken is constantly changing so that the values given in Appendix A represent only a single value from a wide range of concentrations. -These data are used for comparison of data from the -present year with that of past years. Examples of the daily variations in the dissolved oxygen levels can be'seen in the data from groups A2 and D2 in August (Fig. 1), November (Fig. 2), and February (Fig. 3). In the Michigan style ponds the variations in the dissolved oxygen level are magnified due to the consumption of oxygen in the preceding ponds of the series during the day and the surplus of oxygen at night when metabolism is reduced. The magnitude of the variations decreased as the water temperature decreased later in the season (Figs. 4, 5, and 6). As the variations decreased, correlations between the uptake of oxygen and load, density, and number also decreased (Table 4).

Because of the manual adjustment of oxygen supplied to the raceways, oxygen is usually present in surplus when metabolic activity is low and in insufficient amounts when metabolic activity is high. Correction for diel changes in oxygen consumption to maintain a constant dissolved oxygen content at the outflow would require a continuous monitoring system with a feedback mechanism that regulates the flow of oxygen to the individual raceways.

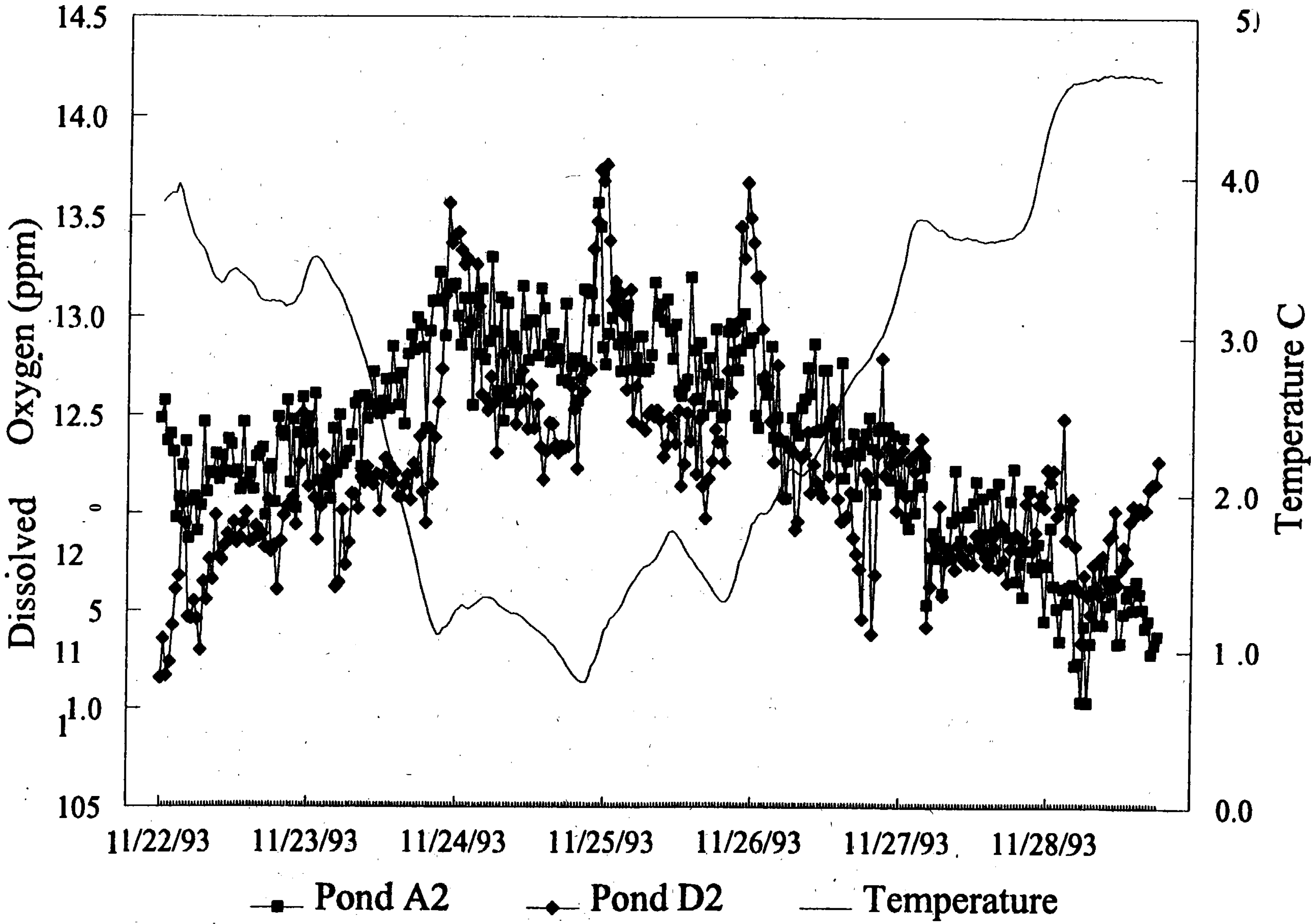
Other metabolic parameters, such as carbon dioxide, pH, and ammonia levels, also undergo diel changes, as well as changes with temperature, feeding, and activity. Although data on these parameters are provided in this report, it should be kept in mind

Fig. 1. Changes in dissolved oxygen at the outflow of ponds A_2 and D_2 during a six day period from 7 August 1993 to 13 August 1993. .



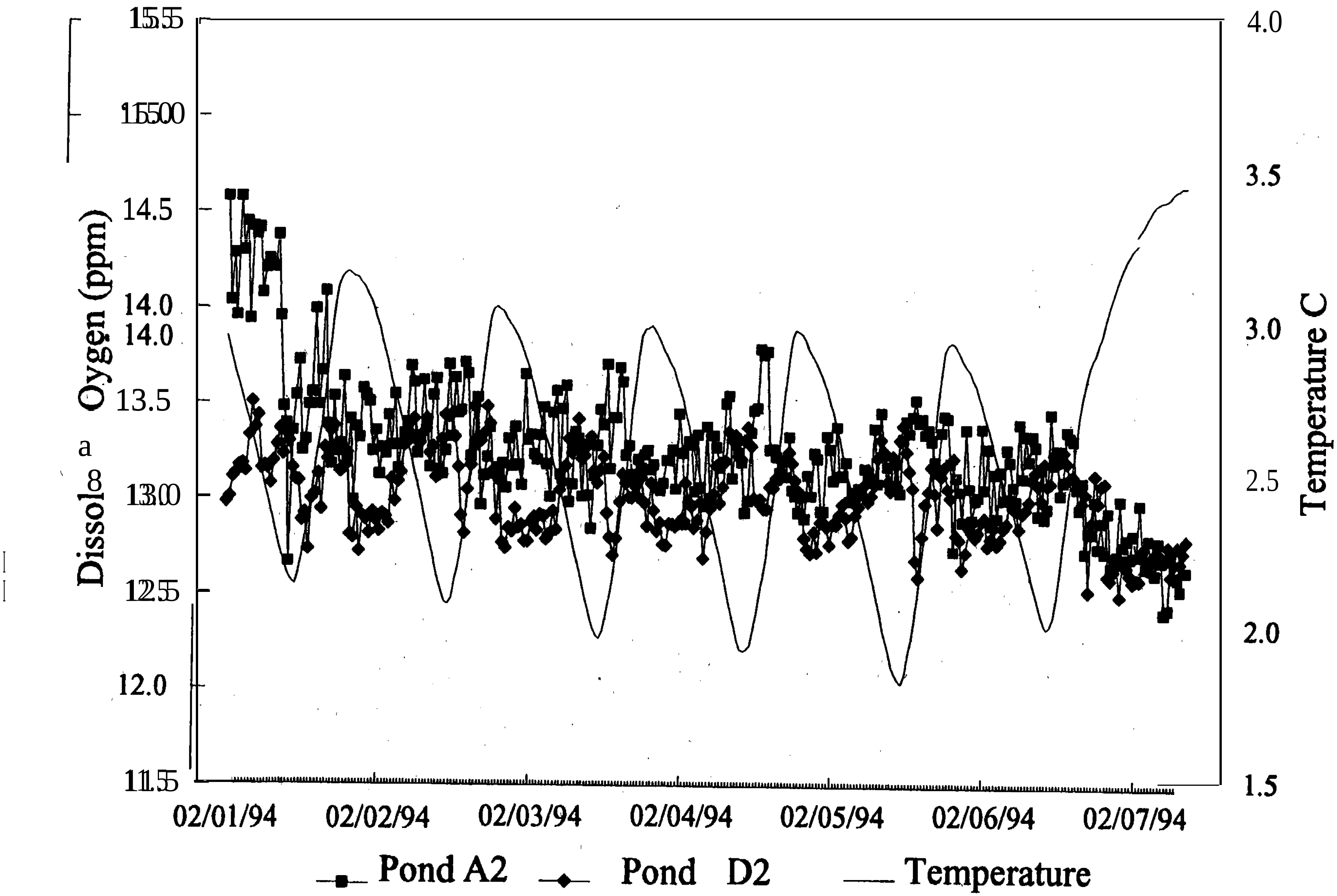
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
Dissolved Oxygen (ppm)
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
Temperature C
08/07/93
08/08/93
08/09/93
08/10/93
08/11/93
08/12/93
08/13/93
Pond A2
Pond D2
Temperature

Fig; 2. Changes in dissolved oxygen at the outflow of ponds A2 and D2 during a six day period from 22 November 1993 to 28 November 1993.



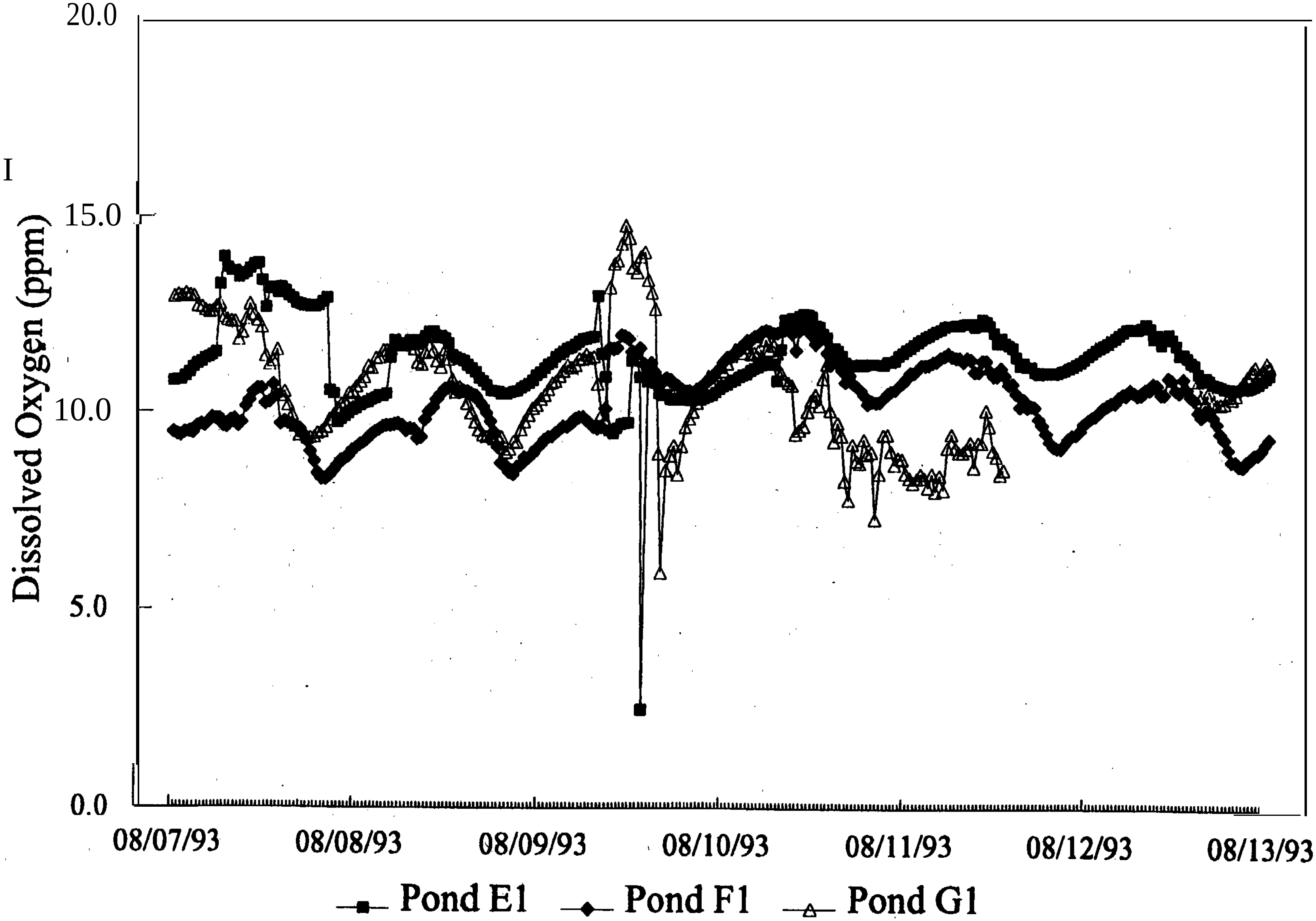
Dissolved Oxygen (ppm)
Temperature C
14.5
14.0
13.5
13.0
12.5
4.0
3.0
2.0
1.0
0.0
11/22/93
11/23/93
11/24/93
11/25/93
11/26/93
11/27/93
11/28/93
Pond A2
Pond D2
Temperature

Fig. 3. Changes in dissolved oxygen at the outflow of ponds A2 and D_2 during a six day period from 1 February 1994 to 7 February 1994.



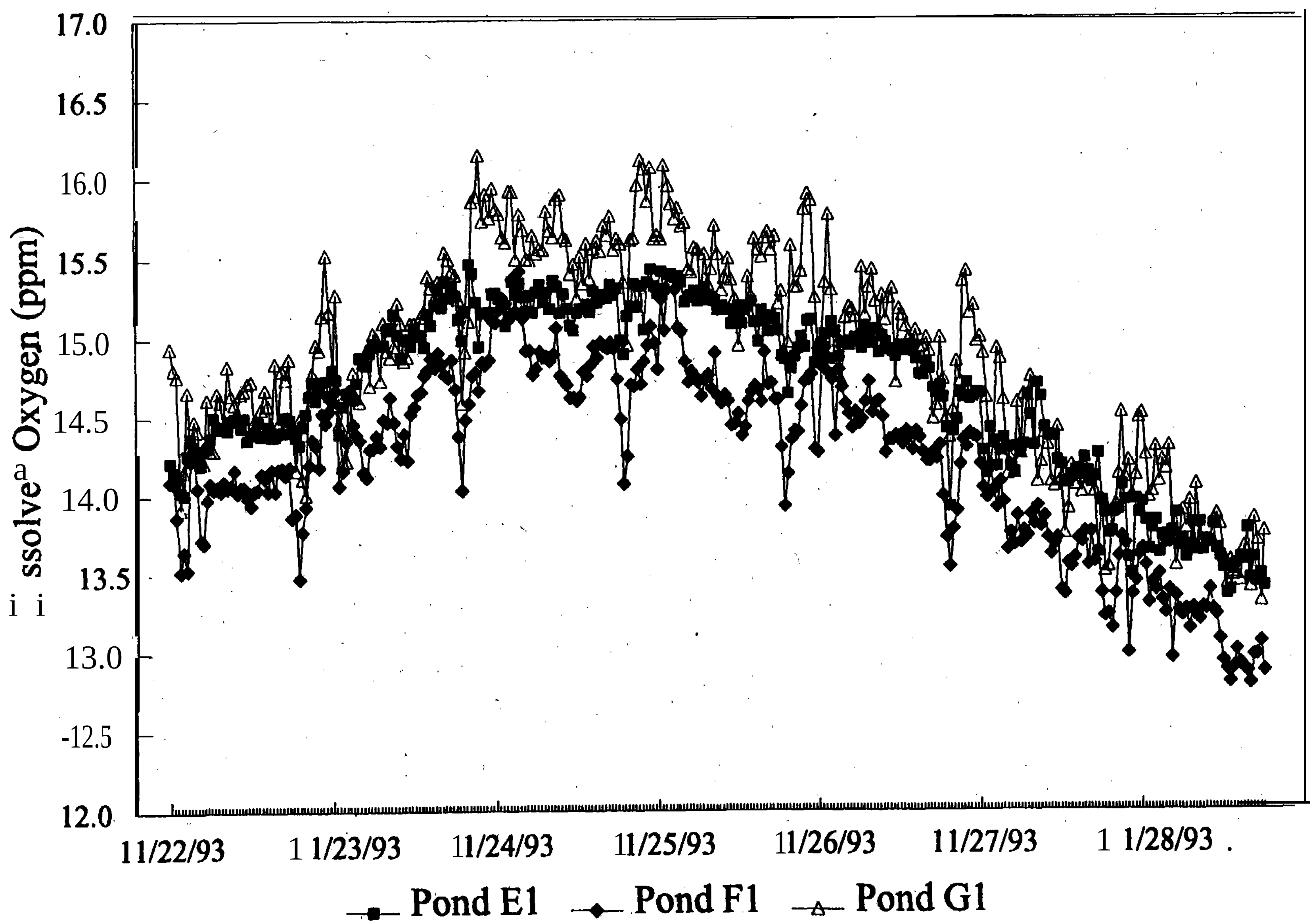
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
Dissol 8 a Oygen (ppm)
4.0
3.5
3.0
2.5
2.0
1.5
Temperature C
02/01/94
02/02/94
02/03/94
02/04/94
02/05/94
02/06/94
02/07/94
Pond A2
Pond D2
Temperature

Fig. 4. Changes in dissolved oxygen at the outflows of ponds El, F_1, and Gl of the Michigan raceways during a six day period from 7 August 1993 to 13 August 1993.



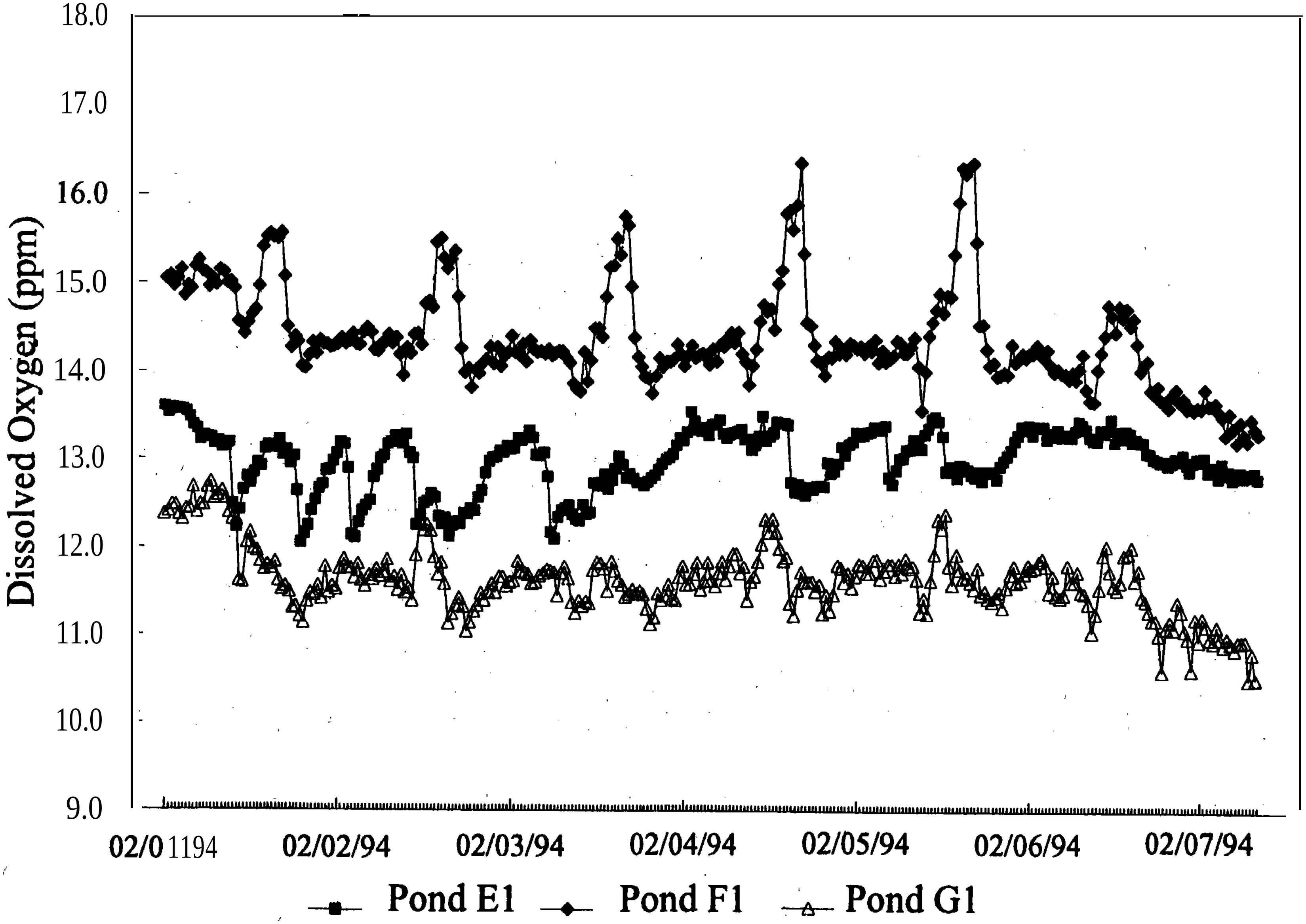
20.0
15.0
10.0
5.0
0.0
Dissolved Oxygen (ppm)
08/07/93
08/08/93
08/09/93
08/10/93
08/11/93
08/12/93
08/13/93
Pond E1
Pond F1
Pond G1

Fig. 5. Changes in dissolved oxygen at the outflows of ponds El, F_1, and G_1 of the Michigan raceways during a six day period from' 22 November 1993 to 28 November 1993.



17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
-12.5
12.0
i issolve^a Oxygen (ppm)
11/22/93
1 1/23/93
11/24/93
11/25/93
11/26/93
11/27/93
1 1/28/93
Pond E1
Pond F1
Pond G1

Fig. 6. Changes in dissolved oxygen at the outflows of ponds E1, F_1, and G1 of the Michigan raceways during a six day period from 1 February 1994 to 7 February 1994.


Dissolved Oxygen (ppm)
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
02/01/94
02/02/94
02/03/94
02/04/94
02/05/94
02/06/94
02/07/94
Pond E1
Pond F1
Pond G1

that these data represent single measurements from continuously changing environments.

Diel patterns are evident in the data collected with the pond monitoring system. A curve fitting program by NCSS (Hintze 1991) was used to find equations that would serve as the basis for a predictive model. The equation that-fit the data had the form:

$$DO = A + BX + CX^2 + DX^3 + EX^4 + FX^5$$

where:

DO = Dissolved oxygen at outflow

X = As a fraction of the day (.25 = 06:00, .5 = 12:00, .75 = 18:00).

The R^2 of the equation ranged from 0.48 to 0.97 if 24-hour periods were described. As additional days of data were added to the analysis the factors changed rapidly and the R^2 value, decreased. An example is shown in Table 5 for the dissolved oxygen concentrations at the outlet of group'D2 starting 2 August, 1993. Other data sets maintained an R^2 greater than 0.7 for the first-2 days but dropped to below 0.2 as 5 days of data were regressed. Sampling limited to a few days at the hatchery would conclude that predictive models could be derived for oxygen utilization but more extensive sampling indicates that these models would probably result in serious errors in estimates of oxygen consumption when longer periods of time are used.

An example of the types of errors which could be made is illustrated by the exponents presented in Table 6. These values were derived for-24-hour periods from August 2 through August 8.

Table 5. The number of days of data for the oxygen outflow at pond D2 starting at August 2, 1993, and the factors for the equation $DC = A + BX + CX^2 + DX^3 + EX? + FX^5$ with the R^2 for that equation where X is the fraction of the day.

Days	A	B	C	D	E	F	R^2
1	9.42	-42.47	359.74	-885.36	872.68	-301.86	0.831
2	10.92	-22.53	206.33	-536.57	546.57	-190.31	0.283
3	10.93	-11.92	122.11	-329.94	335.46	-115.89	0.241
4	10.56	-4.42	75.21	-226.18	238.32	-83.20	0.256
5	10.06	1.19	37.19	-141.82	164.57	-61.19	0.186
6	10.24	0.93	35.62	-130.72	150.10	-55.67	0.087

Table 6. Exponents for the equation $DO = A + BX + CX^2 + DX^3 + EX^4 + FX^5$ derived from oxygen measurement at the outflow of pond D2. Data is derived for the single days indicated..

Date	A	B	C	D-	E	F	R^2
Aug 2	9.42	-42.47	359.74	-885.36	872.68	-301.86	0.831
Aug 3	12.40	-2.78	54.80	-192.91	219.97	-80.84	0.970
Aug 4	11.01	-6.98	-27.94	34.81	-29.02	13.43	0.966
Aug 5	9.51	16.14	-50.54	46.12	-11.32	-1.00	0.951
Aug 6	8.92	15.78	-55.98	43.22	24.15	-27.61	0.670
Aug 7	9.28	5.74	2.98	-53.00	77.25	31.95	0.530
Aug 8	10.46	-3.39	64.88	-210.49	241.41	-92.20	0.652

If data were only collected on August 3'and 4, one would conclude that the basal level of oxygen consumption was higher than if the information was collected on August 5 and 6.

From our first approximations, it seems unlikely that highly predictive models of oxygen consumption under hatchery conditions can be'derived due to the day to day variables that can not be controlled. Conditions like feeding (number of times per day, time of day, and quantity delivered at each feeding), water temperature, biomass and water quality would have to be accounted for in order for a predictive model to be valid.

pH

pH was sampled at weekly intervals throughout the rearing period for spring chinook salmon (Table 7). Data collected was combined for each group of duplicate'ponds. Analysis of variance and Fisher least significant difference tests ($P < 0.05$) indicated differences between groups (Fig. 7). pH of the effluent decreased as the density of fish per pond-increased. This is the same pattern seen in past years, but the magnitude of the variation was influenced by water quality. The weekly average obtained from the continuous monitoring system (Table 8) showed the same relationship of decreasing pH with increasing numbers of fish. Diel variations in pH with time are shown for eight day periods from 7 August 1993 to 15 August 1993 for ponds A_2 and D_2 (Fig. 8) and the Michigan pond series (Fig. 9).

The relationship between the decrease in pH and the decrease in dissolved oxygen at the effluent seemed to vary somewhat

Table 7. pH values at the inflow and outflow of various experimental ponds collected as single samples at Willamette Hatchery, 1993-94.

Date	Inflow	Inflow	A1	A2	B1	B2	C1	C2	D1	D2	Inflow	Inflow	E1	E2	F1	F2	G1	G2
08/03/93	7.74		7.67		7.69		7.65		7.63		7.81		7.79		7.69		7.64	
08/05/93		7.50		7.38		7.41		7.33		7.29		7.43		7.38		7.36		7.32
08/10/93	7.61		7.47		7.53		7.44		7.31		7.65		7.53		7.43		7.26	
08/12/93		7.91		7.74		7.82		7.67		7.49		7.92		7.87		7.75		7.62
08/17/93	7.89		7.74		7.80		7.70		7.56		7.90		7.84		7.68		7.50	
08/19/93		7.92		7.72		7.82		7.66		7.49		7.98		7.85		7.67		7.51
08/24/93	7.70		7.48		7.57		7.44		7.30		7.92		7.65		7.45		7.26	
08/26/93		7.87		7.68		7.82		7.64		7.54		7.90		7.83		7.72		7.58
08/31/93	7.70		7.54		7.65		7.48		7.35		7.66		7.58		7.41		7.27	
09/02/93		7.78		7.57		7.66		7.48		7.37		7.66		7.63		7.52		7.40
09/07/93	7.88		7.68		7.74		7.60		7.44		7.92		7.82		7.59		7.37	
09/09/93		7.63		7.40		7.49		7.32		7.20		7.67		7.57		7.38		7.22
09/14/93	7.54		7.36		7.41		7.32		7.21		7.64		7.54		7.37		7.21	
09/16/93		7.70		7.53		7.57		7.40		7.31		7.79		7.64		7.47		7.34
09/21/93	7.59		7.43		7.49		7.40		7.33		7.58		7.53		7.45		7.33	
09/23/93		7.73		7.63		7.75		7.57		7.54		7.88		7.76		7.71		7.62
09/28/93	7.85		7.67		7.73		7.64		7.54		7.95		7.88		7.71		7.55	
09/30/93		7.88		7.43		7.50		7.38		7.31		7.90		7.83		7.69		7.41
10/05/93	7.70		7.57		7.63		7.48		7.34		7.71		7.67		7.51		7.35	
10/07/93		7.73		7.43		7.53		7.37		7.22		7.79		7.68		7.51		7.38
10/12/93	7.66		7.36		7.43		7.30		7.16		7.70		7.51		7.31		7.16	
10/14/93		7.68		7.36		7.45		7.30		7.15		7.76		7.58		7.44		7.28
10/19/93	7.84		7.39		7.75		7.40		7.30		7.68		7.58		7.44		7.28	
10/21/93		7.89		7.61		7.81		7.64		7.30		7.93		7.77		7.58		7.41
10/26/93	7.88		7.61		7.75		7.64		7.43		7.90		7.72		7.52		7.36	
10/28/93		7.92		7.68		7.79		7.60		7.36		7.94		7.82		7.62		7.45
11/02/93	7.84		7.52		7.71		7.54		7.41		7.80		7.74		7.58		7.40	
11/04/93		7.89		7.68		7.81		7.62		7.47		7.99		7.87		7.67		7.51
11/09/93	7.95		7.65		7.73		7.60		7.52		8.01		7.88		7.69		7.56	
11/11/93		7.95		7.68		7.74		7.65		7.58		8.00		7.89		7.70		7.59
11/16/93	8.03		7.71		7.76		7.72		7.60		8.03		7.92		7.72		7.59	
11/18/93		7.99		7.69		7.76		7.70		7.62		8.00		7.93		7.75		7.60
11/22/93	7.90		7.66		7.72		7.64		7.59		7.95		7.90		7.79		7.66	
11/24/93		7.86		7.69		7.71		7.66		7.62		7.94		7.79		7.74		7.64
11/30/93	7.82		7.63		7.68		7.63		7.61		8.00		7.78		7.72		7.61	
12/02/93		7.82		7.59		7.63		7.56		7.56		7.88		7.83		7.71		7.61
12/08/93	7.58		7.40		7.46		7.34		7.18		7.88		7.61		7.24		7.09	
12/10/93		- -		- -		- -		- -		- -		- -		- -		- -		- -
12/14/93	7.83		7.65		7.75		7.63		7.44		7.86		7.69		7.42		7.30	
12/16/93		7.84		7.68		7.74		7.67		7.50		7.85		7.70		7.59		7.47

Table 7. pH values et the inflow end outflow of various experimental ponds collected as single samples at Willamette Hatchery, 1993-94.

Date	Inflow	Inflow	A1	A2	B1	B2	C1	c2	D1	D2	Inflow	Inflow	E1	E2	f1	f2	G1	G2
01/06/94		. .		. .		. .		. .		. .		. .		. .		. .		. .
01/11/94	7.70		7.54		7.58		7.50		7.41		7.74		7.67		7.54		7.40	
01/13/94		7.67		7.48		7.53		7.45		7.37		7.78		7.68		7.54		7.39
01/18/94	7.71		7.50		7.43		7.53		7.45		7.75		7.69		7.58		7.44	
01/20/94		7 . n		7.61		7.65		7.56		7.49		7.77		7.73		7.64		7.54
01/25/94	7.80		7.66		7.78		7.64		7.54		7.86		7.76		7.65		7.53	
01/27/94		7.83		7.68		7.74		7.67		7.58		7.88		7.83		7.71		7.61
02/01/94	7.80		7.72		7.72		7.69		7.62		7.89		7.80		7.71		7.57	
02/03/94		7.82		7.55		7.72		7.69		7.59		7.84		7.81		7.72		7.63
02/08/94	7.83		7.74		7.74		7.67		7.64		7.82		7 . 0		7.75		7.66	
02/10/94		7.88		7.79		7.81		7.77		7.72		7.91		7.90		7.82		7.73
02/15/94	7.88		7.76		7.78		7.76		7.69		7.98		7.92		7.80		7.67	
02/17/94		7.88		7.76		7.78		7.76		7.69		7.98		7.92		7.80		7.67

Fig. 7. Average pH values for effluents of Various experimental raceways at Willamette Hatchery, 1993-1994.. pH values were averaged over the rearing period. Values for replicates were combined. Bars with the same small superscript letter are not significantly different ($P < 0.05$).

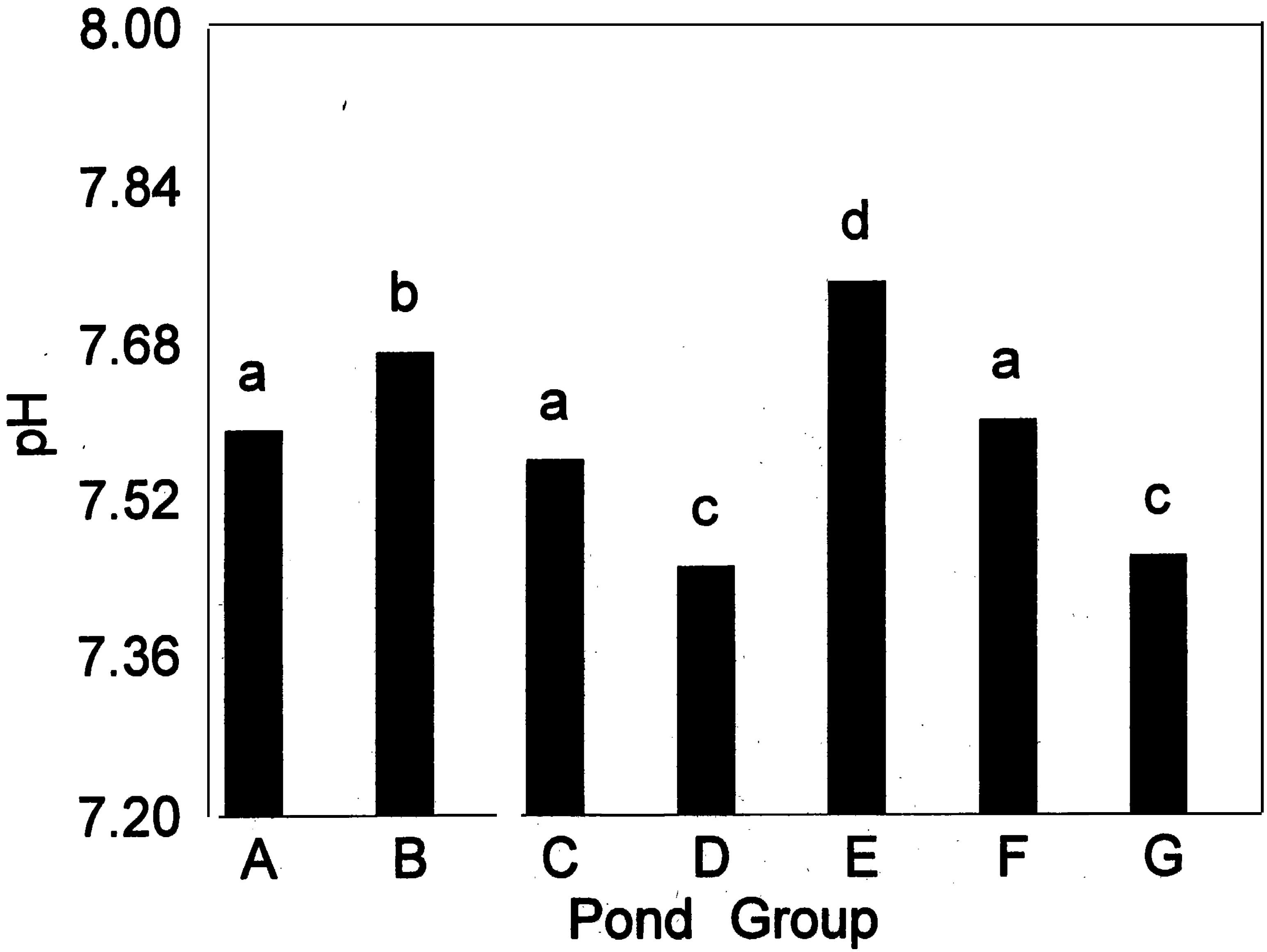
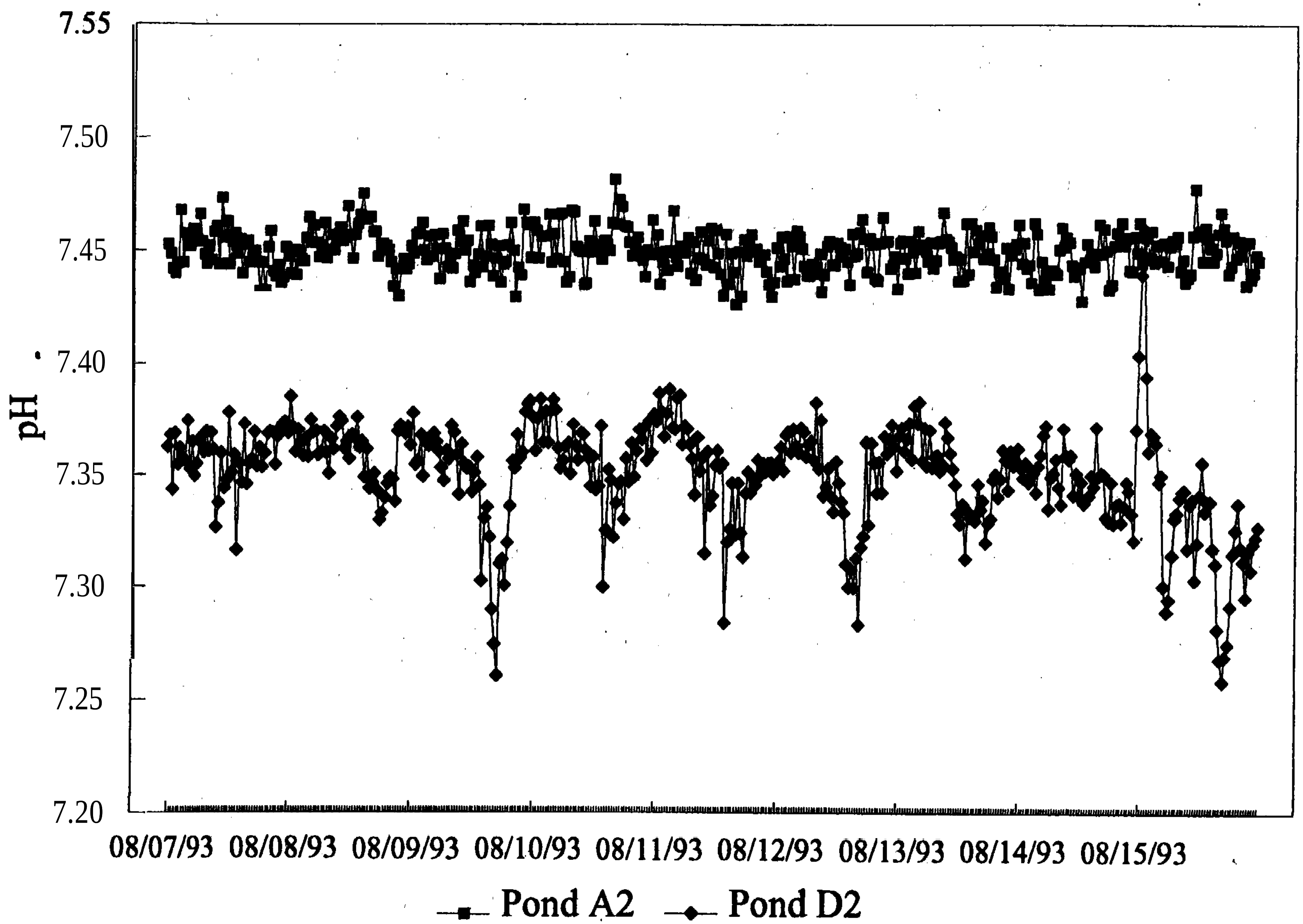

8.00
7.84
7.68
7.52
7.36
7.20
pH
a
b
a
c
d
a
c
A
B
C
D
E
F
G
Pond Group

Table 8. Weekly average pH values and temperature from inflow and outflow of experimental ponds as measured by the data monitoring system at Willamette Hatchery, 1993-1994

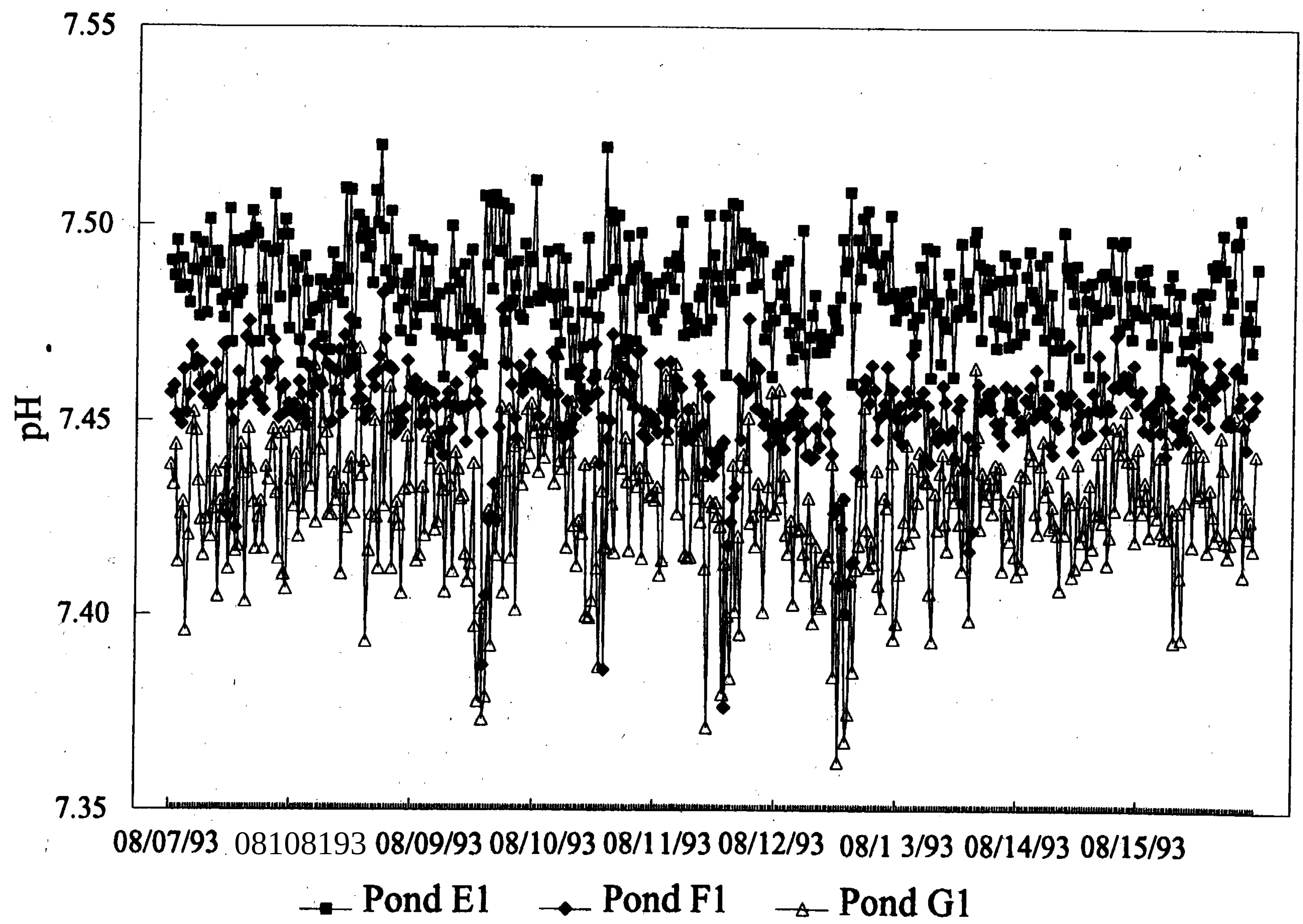
Date	Inflow	A2	B2	C2	D2	Inflow	E1	F1	G1	Temp. C
08/01/93	- -	7.35	7.55	7.41	7.32	7.56	7.47	7.43	7.40	14.8
08/08/93	- -	7.45	7.59	7.40	7.35	7.54	7.48	7.45	7.43	13.7
08/15/93	- -	7.56	7.68	7.54	7.42	7.87	7.58	7.40	7.28	12.6
08/22/93	- -	7.51	7.70	7.53	7.37	8.06	7.59	7.38	7.25	12.1
08/29/93	7.80	7.49	7.71	7.53	7.34	8.08	7.63	7.38	7.25	12.0
09/05/93	7.91	7.50	7.71	7.54	7.36	8.01	7.65	7.39	7.26	13.1
09/12/93	7.90	7.50	7.68	7.50	7.39	7.98	7.65	7.39	7.27	10.9
09/19/93	7.89	7.50	7.66	7.49	7.39	7.98	7.65	7.39	7.26	9.3
09/26/93	7.90	7.50	7.59	7.45	7.37	7.98	7.66	7.38	7.26	10.7
10/03/93	7.90	7.50	7.53	7.45	7.39	7.99	7.66	7.39	7.30	10.2
10/10/93	7.89	7.50	7.52	7.45	7.40	7.98	7.65	7.39	7.31	10.1
10/17/93	7.89	7.52	7.57	7.47	7.41	7.98	7.64	7.39	7.31	8.5
10/24/93	7.88	7.58	7.78	7.49	7.43	7.87	7.61	7.38	7.31	8.2
10/31/93	7.86	7.58	7.78	7.61	7.40	7.85	7.58	7.37	7.31	6.1
11/07/93	7.85	7.57	7.76	7.59	7.41	7.84	7.57	7.37	7.30	5.0
11/14/93	7.84	7.56	7.75	7.58	7.40	7.84	7.56	7.36	7.30	4.2
11/21/93	7.82	7.56	7.74	7.57	7.40	7.83	7.55	7.36	7.30	2.6
11/28/93	7.84	7.65	7.75	7.58	7.55	7.87	7.63	7.50	7.47	5.3
12/05/93	7.85	7.67	7.77	7.60	7.55	7.89	7.65	7.53	7.51	5.5
12/12/93	7.83	7.66	7.75	7.60	7.53	7.88	7.63	7.52	7.45	4.2
12/19/93	7.81	7.65	7.74	7.59	7.52	7.87	7.61	7.51	7.41	2.0
12/26/93	7.83	7.65	7.74	7.60	7.51	7.87	7.61	7.52	7.41	3.7
01/02/94	7.86	7.67	7.77	7.63	7.52	7.89	7.63	7.52	7.41	5.3
01/09/94	7.85	7.67	7.77	7.62	7.53	7.89	7.62	7.51	7.40	4.7
01/16/94	7.85	7.67	7.77	7.63	7.54	7.88	7.64	7.52		5.2
01/23/94	7.84	7.65	7.76	7.62	7.65	7.85	7.68	7.54	....	3.2
01/30/94	7.84	7.65	7.76	7.62			7.66	7.54	7.47	2.8
									7.47	
02/06/94	7.85	7.66	7.76	7.62	7.64	7.85	7.65	7.55	7.47	3.9
02/13/94	7.85	7.67	7.76	7.62	7.64	7.85	7.65	7.55	7.47	4.5
02/20/94	7.86	- -	7.77	7.63	7.64	7.85	7.65	7.55	7.47	5.7

Fig. 8. Changes in pH of effluent from experimental groups A_2 and D_2 over an eight day period from 7 August 1993 to 15 August 1993.



7.55
7.50
7.45
7.40
7.35
7.30
7.25
7.20
pH
08/07/93 08/08/93 08/09/93 08/10/93 08/11/93 08/12/93 08/13/93 08/14/93 08/15/93
Pond A2
Pond D2

Fig. 9. Chapges in pH of effluent from the Michigan ponds series, groups El, F_1, and Gl, over an eight day period. from 7 August 1993 to 15 August 1993.


7.55
7.50
7.45
7.40
7.35
pH
08/07/93
08108193
08/09/93
08/10/93
08/1 1/93
08/12/93
08/1 3/93
08/14/93
08/15/93
Pond E1
Pond F1
Pond G1

from that originally described. In the high density ponds, pH tended to decrease before dissolved oxygen levels decreased. Often the pH of the effluent was rising as the dissolved oxygen level was decreasing. Feed is presented daily.to the fish over a short interval and the fish actively seek the food. This may cause a surge in metabolism and carbon dioxide production and an oxygen deficit within the body. This remains to be determined.

Alkalinity

Changes in alkalinity are important to the present experiment in that they reflect the ability of the surface water to buffer changes in pH resulting from production of metabolic CO_2. Analysis of variance ($P \leq 0.05$) did not show significant differences between-alkalinity at the outflows from the different groups (Ewing and Sheahan 1992, Ewing and Sheahan 1991) and the testing was reduced to three replicate samples of the incoming water (Table 9). Variations throughout the year were associated with rainfall (Table 10). As the rainfall increased, alkalinity of the water decreased (correlation coefficient $R = -.481$ for a 5 day moving average). The relationship between alkalinity in ppm and the daily rainfall is shown in Fig. 10.

Table 9. Water alkalinity (as mg $CaCO_3$/L) for the inflowing water at Willamette Hatchery, 1993-94.

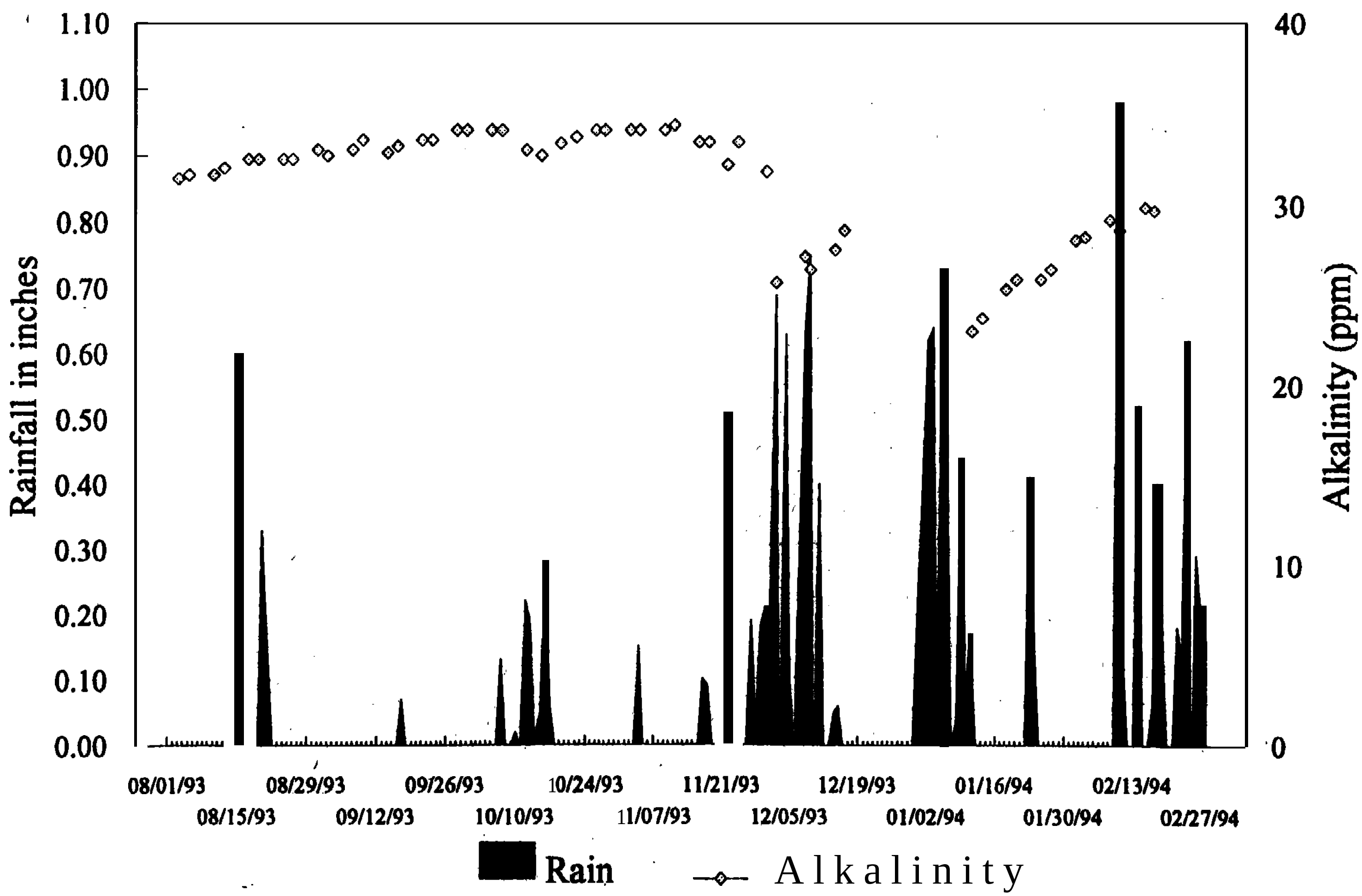
Date	1	2	3	Average	Date	1	2	3	Average
08/03/93	31.5	31.5	31.5	31.5	08/05/93	32.0	31.5	31.5	31.7
08/10/93	31.5	31.5	32.0	31.7	08/12/93	32.0	32.0	32.0	32.0
08/17/93	32.6	32.6	32.6	32.6	08/19/93	32.6	32.6	32.6	32.6
08/24/93	32.6	32.6	32.6	32.6	08/26/93	32.6	32.6	32.6	32.6
08/31/93	33.1	33.1	33.1	33.1	09/02/93	32.6	32.6	33.1	32.7
09/07/93	33.1	33.1	33.1	33.1	09/09/93	33.6	33.6	33.6	33.6
09/14/93	32.6	33.1	33.1	32.9	09/16/93	33.6	33.1	33.1	33.3
09/21/93	33.6	33.6	33.6	33.6	09/23/93	33.6	33.6	33.6	33.6
09/28/93	34.1	34.1	34.1	34.1	09/30/93	34.1	34.1	34.1	34.1
10/05/93	34.1	34.1	34.1	34.1	10/07/93	34.1	34.1	34.1	34.1
10/12/93	33.1	33.1	33.1	33.1	10/15/93	33.6	33.6	31.1	32.8
10/19/93	33.1	33.6	33.6	33.4	10/22/93	33.6	34.1	33.6	33.8
10/26/93	34.1	34.1	34.1	34.1	10/28/93	34.1	34.1	34.1	34.1
11/02/93	34.1	34.1	34.1	34.1	11/04/93	34.1	34.1	34.1	34.1
11/09/93	34.1	34.1	34.1	34.1	11/11/93	34.6	34.0	34.6	34.4
11/16/93	33.5	33.5	33.5	33.5	11/18/93	33.5	33.5	33.5	33.5
11/22/93	31.9	32.4	32.4	32.2	11/24/93	33.5	33.5	33.5	33.5
11/30/93	31.9	31.9	31.9	31.9	12/02/93	25.4	25.9	25.9	25.7
12/08/93	27.5	27.0	27.0	27.2	12/09/93	26.5	26.5	26.5	26.5
12/14/93	27.5	27.5	27.5	27.5	12/16/93	28.6	28.6	28.6	28.6
12/21/93	- -	- -	- -	- -	12/23/93	- -	- -	- -	- -
12/28/93	- -	- -	- -	- -	12/30/93	- -	- -	- -	- -
01/04/94	- -	- -	- -	- -	01/06/94	- -	- -	- -	- -
01/11/94	22.7	23.2	23.2	23.0	01/13/94	23.8	23.8	23.8	23.8
01/18/94	25.4	25.4	25.4	25.4	01/20/94	25.9	25.9	25.9	25.9
01/25/94	25.9	25.9	25.9	25.9	01/27/94	26.5	26.5	26.5	26.5
02/01/94	28.1	28.1	28.1	28.1	02/03/94	28.6	28.1	28.1	28.3
02/08/94	29.2	29.2	29.2	29.2	02/10/94	28.6	28.6	28.6	28.6
02/15/94	29.7	29.7	30.2	29.9	02/17/94	29.7	29.7	29.7	29.7

Table 10. Daily rainfall in inches at Willamette Hatchery for the rearing cycle from August 1993 to February 1994:

Date	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	0.00	0.00	0.00	0.00	0.21	0.40	0.00
2	0.00	0.00	0.00	0.00	0.69	0.62	0.00
3	o:oo	0.00	0.00	0.00	0.00	0.64	0.00
5	0.00	0.00	0.00	0.15	0.63	0.15	0.00
6	0.00	0.00	0.00	0.00	0.10	0.73	0.00
	0.00	0.00	0.00	0.00	0.00	0.46	0.00
7	0.00	0.00	0.13	0.00	0.32	0.00	0.00
8	0.00	0.00	T	0.00	0.63	0.04	0.00
9	0.00	0.00	0.00	0.00	0.75	0.44	0.00
10	0.00	0.00	0.02	0.00	0.00	0.09	0.98
11	0.00	0.00	0.00	0.00	0.40	0.17	0.15
12	0.00	0.00	0.22	0.00	0.00	0.00	0.00
14	0.00	0.00	0.19	T	0.00	0.00	0.00
15	0.00	0.00	0.01	0.00	0.05	0.00	0.52
		0.00	0.05	0.00	0.06	T	0.00
16	0.60	0.00	0.28	T	0.00	0.00	0.00
17	0.01	0.07	0.06	0.10	o:oo	0.00	0.06
18	0.00	0.00	o:oo	0.09	0.00	0.00	0.40
19	0.00	0.00	0.00	0.00	0.00	0.00	0.22
20	0.33	0.00	0.00	0.00	0.00	0.00	0.00
21	0.15	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.51	o:oo	0.00	0.18
23	0.00	0.00	o:oo	0.19	0.00	0.41	0.14
24	0.00	0.00	T	T	0.00	0.16	0.62
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.29
27	o:oo	0.00	0.00	0.19	0.00	0.00	0.19
28	0.00	0.00	0.00	0.04	o:oo	0.00	-0.16
29		0.00	0.00	0.18	0.00	0.00	
30	0.00	0.00	0.00	0.21	0.00	0.00	
31	0.00		0.00		0.19	0.00	
TOTAL	T-37	0.07	0.96	1.66	4-m	4.31	3.91

T = Trace amount of precipitation recorded.

Fig. 10. Relationship between rainfall and alkalinity of inflow to experimental groups at Willamette Hatchery, 1993-1994.



Rainfall in inches
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Alkalinity (ppm)
40
30
20
10
0
08/01/93
08/15/93
08/29/93
09/12/93
09/26/93
10/10/93
10/24/93
11/07/93
11/21/93
12/05/93
12/19/93
01/02/94
01/16/94
01/30/94
02/13/94
02/27/94
Rain
Alkalinity

Ammonia

Weekly ammonia production for experimental groups is presented in Table 11. Data from replicate raceways in each experimental group were combined for statistical analysis. Analysis of variance and Fisher least significant difference tests of the-combined data indicated differences ($P < 0.05$) between groups (Fig. 11). As the number of fish in a raceway increased, the amount of ammonia in the effluent increased.

Cyclic changes in ammonium ion production were examined at three times during the rearing year: September 15, December 15, and February 27. These changes were examined in relation to the changes in oxygen consumption; carbon dioxide production, and water temperature provided by the Royce continuous monitoring system.

During the September 15 sampling, die1 cycles in-ammonium ion production were. found for all ponds. Examples of these cycles are shown for ponds A and D (Fig. 12)and for the Michigan ponds (Fig. 13). Levels of ammonium ions in the water corresponded closely to water temperature.

During the December sampling, die1 cycles in ammonium ion 'production were much less evident and did not correlate with other environmental or metabolic parameters. Examples of the cycles are shown for groups A and D (Fig. 14) and for the Michigan ponds (Fig. 15). During the February sampling, no die1 cycles were found, no correla-tions with environmental or

Table 11. Unionized ammonia concentrations (mg/L) at the inflow and outflow of experimental ponds at Willamette Hatchery, 1993-94.

Date	Inflow,	Inflow	A1	A2	B1	B2	C1	C2	D1	D2	Inflow	Inflow	E1	E2	F1	F2	G1	G2
08/03/93	0.05		0.11		0.08		0.07		0.19		0.04		0.09		0.29		0.32	
08/05/93		0.00		0.12		0.04		0.06		0.29		0.00		0.05		0.13		0.26
08/10/93	0.02		0.12		0.08		0.10		0.15		0.05		0.12		0.25		0.37	
08/12/93		0.02		0.13		0.07		0.14		0.27		0.05		0.12		0.25		0.42
08/17/93	0.02		0.21		0.10		0.12		0.21		0.03		0.14		0.27		0.49	
08/19/93		0.03		0.15		0.06		0.13		0.36		0.00		0.14		0.33		0.52
08/24/93	0.03		0.14		0.09		0.09		0.19		0.03		0.14		0.28		0.41	
08/26/93		0.02		0.14		0.07		0.09		0.20		0.05		0.12		0.22		0.35
08/31/93	0.05		0.30		0.15		0.12		0.17		0.07		0.17		0.38		0.57	
09/02/93		0.02		0.17		0.07		0.12		0.37		0.00		0.23		0.23		0.42
09/07/93	0.01		0.11		0.11		0.07		0.30		0.02		0.15		0.34		0.48	
09/09/93		0.05		0.20		0.15		0.11		0.49		0.02		0.18		0.43		0.60
09/14/93	0.03		0.19		0.13		0.11		0.28		0.03		0.16		0.33		0.44	
09/16/93		0.02		0.16		0.09		0.14		0.22		0.01		0.14		0.21		0.31
09/21/93	0.01		0.00		0.04		0.07		0.13		0.01		0.11		0.11		0.28	
09/23/93		0.01		0.10		0.06		0.10		0.19		0.04		0.10		0.19		0.23
09/28/93	0.00		0.16		0.11		0.14		0.25		0.02		0.17		0.37		0.51	
09/30/93		0.03		0.11		0.11		0.12		0.48		0.05		0.16		0.32		0.36
10/05/93	0.01		0.17		0.08		0.10		0.24		0.01		0.15		0.23		0.43	
10/07/93		0.04		0.16		0.12		0.13		0.53		0.04		0.16		0.26		0.40
10/12/93	0.00		0.23		0.10		0.10		0.23		0.02		0.11		0.37		0.55	
10/14/93		0.81		0.17		0.11		0.09		0.43		0.01		0.18		0.28		0.41
10/19/93	0.01		0.11		0.04		0.07		0.15		0.01		0.06		0.16		0.24	
10/21/93		0.02		0.15		0.05		0.13		0.31		0.03		0.13		0.19		0.32
10/26/93	0.02		0.15		0.08		0.09		0.14		0.03		0.10		0.27		0.33	
10/28/93		0.02		0.17		0.08		0.14		0.30		0.02		0.13		0.19		0.28
11/02/93	0.02		0.10		0.04		0.03		0.10		0.01		0.08		0.12		0.22	
11/04/93		0.02		0.07	0.04	0.04		0.09		0.20		0.04		0.07		0.12		0.25
11/09/93	0.04		0.08				0.10		0.13		0.04		0.06		0.11		0.13	
11/11/93		0.04		0.08		0.06		0.06		0.11		0.01		0.09		0.11		0.15
11/16/93	0.00		0.09		0.06		0.06		0.14		0.04		0.08		0.17		0.19	
11/18/93		0.04		0.09		0.08		0.10		0.09		0.04		0.10		0.17		0.18
11/22/93	0.03		0.05		0.03		0.02		0.06		0.01				0.10		0.12	
11/24/93		0.01		0.04		0.03		0.04		0.17		0.00	0.05	0.03		0.12		0.13
11/30/93	0.02		0.07		0.02		0.03		0.09		0.00				0.09		0.14	
12/02/93		0.02		0.07		0.05		0.10		0.10		0.02		0.07		0.12		0.17
12/08/93	0.01		0.08		0.04		0.08		0.17		0.04		0.13		0.18		0.17	
12/10/93		0.06		0.07		0.06		0.06		0.10		0.01		0.07		0.14		0.16
12/14/93	0.00		0.06		0.04		0.04		0.10		0.02		0.06		0.12		0.18	
12/16/93		0.03		0.88		0.09		0.04		0.11		0.05		0.03		0.13		0.18

Table 11. Unionized ammonia concentrations (mg/L) at the inflow and outflow of experimental ponds at Willamette Hatchery, 1993-94.

Date	fnf Low	Inflow	A1	A2	B1	B2	C1	c2	D1	D2	Inflow	Inflow	E1	E2	F1	F2	G1	G2
12/21/93	- -						- -		- -		- -		- -		- -		- -	
12/23/93		- -		- -		- -		- -		- -		- -		- -		- -		- -
12/28/93	- -		- -		- -		- -		- -		- -		- -		- -		- -	
12/30/93		- -		- -		- -		- -		- -		- -		- -		- -		- -
01/04/94	- -		- -		- -		- -		- -		- -		- -		- -		- -	
01/06/94		- -		- -		- -		- -		- -		- -		- -		- -		- -
01/11/94	0.03		0.07		0.08		0.06		0.15		0.04		0.07		0.13		0.31	
01/13/94		0.09		0.19		0.17		0.15		0.19		0.04		0.15		0.21		0.32
01/18/94	0.03		0.06		0.04		0.02		0.03		0.02		0.04		0.06		0.10	
01/20/94		0.03		0.06		0.08		0.08		0.14		0.05		0.13		0.16		0.21
01/25/94	0.02		0.09		0.05		0.02		0.07		0.00		0.04		0.12		0.21	
01 27/94		4.03		0.06		0.04		0.06		0.11		0.04		0.06		0.10		0.11
02/01/94	0.02		0.03		0.03		0.02		0.02		0.02		0.03		0.05		0.06	
02/03/94		0.00	6.05'	0.01		0.05		0 . 0 3		0.08	0.00	0.03		0.10		0.17		0.11
02/08/94	0.00				0.02		0.02		0.03				0.04		0.10		0.14	
02/10/94		0.00		0.06		0.00		0.01		0.04		0.01		0.03		0.06		0.06
02/15/94	0.02		0.12		0.09		0.06		0.08		0.02		0.07		0.18		0.25	
02/17/94		0.01		0.10		0.06		0.07		0.13		0.01		0.09		0 . 1 7		0.23

Fig. 11. Average ammonia concentrations (ug/L) for effluents of various experimental raceways at Willamette Hatchery, 1993-1994. Ammonia values were averaged over the rearing period. Values for replicate groups were combined. Bars with the same small, superscript letter are not significantly different (P < 0.05):

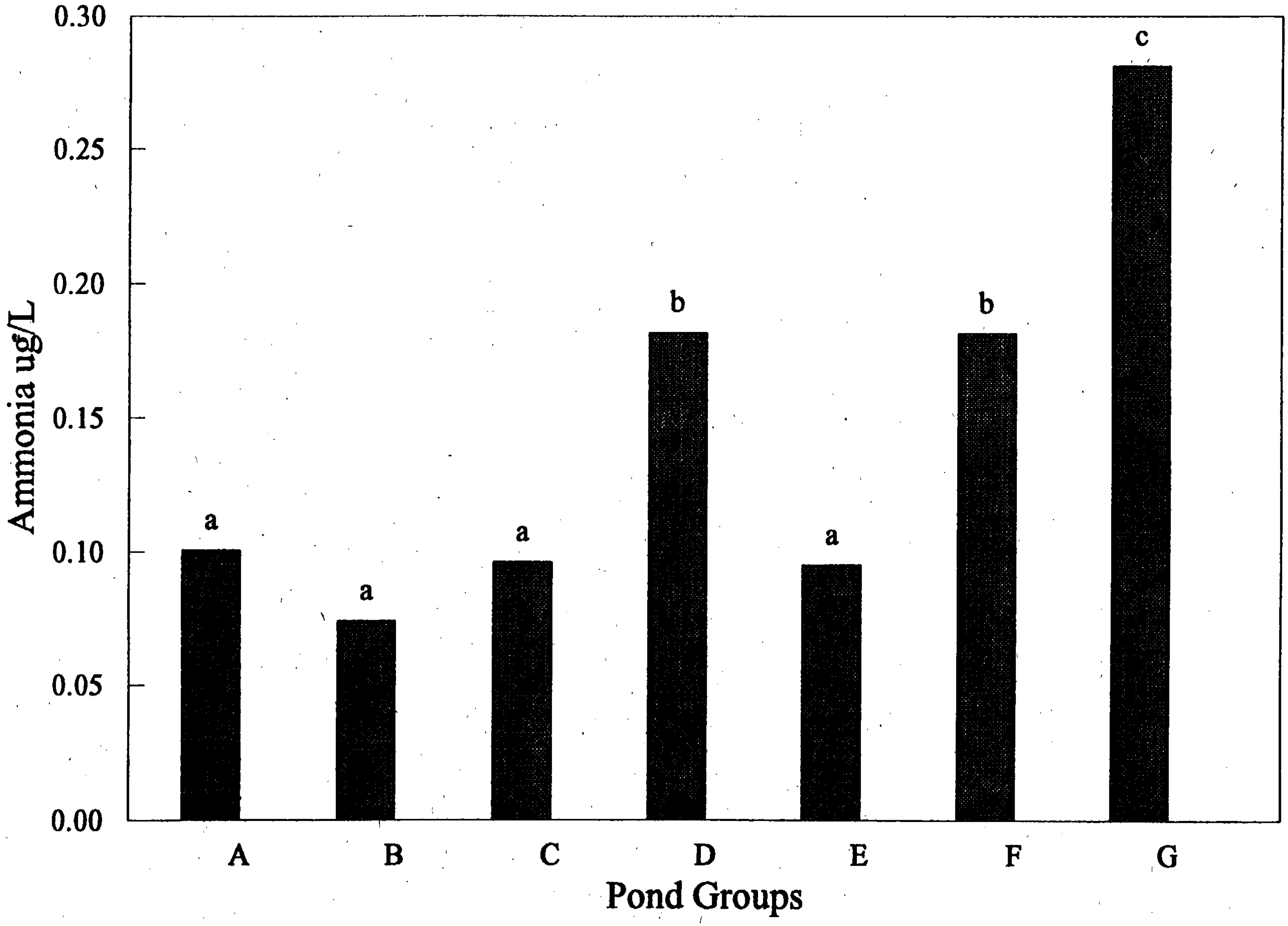

0.30
0.25
0.20
0.15
0.10
0.05
0.00
Ammonia ug/L
a
a
a
b
a
b
c
A
B
C
D
E
F
G
Pond Groups

Fig. 12. Changes in ammonium ion concentration in the effluent from groups A (-■-) and D (-□-) during hourly sampling from 15 September 1993 to 16 September 1993.

Groups A and D
September 15-16, 1993

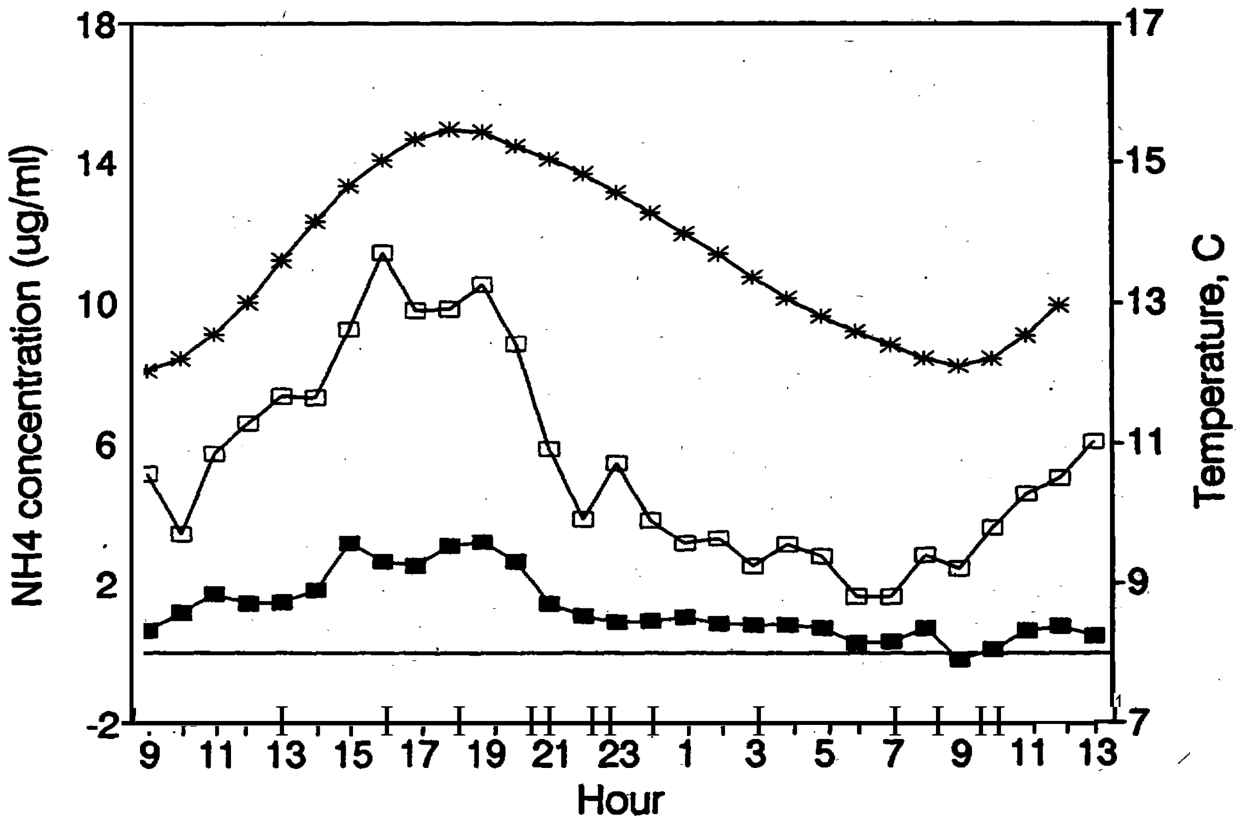
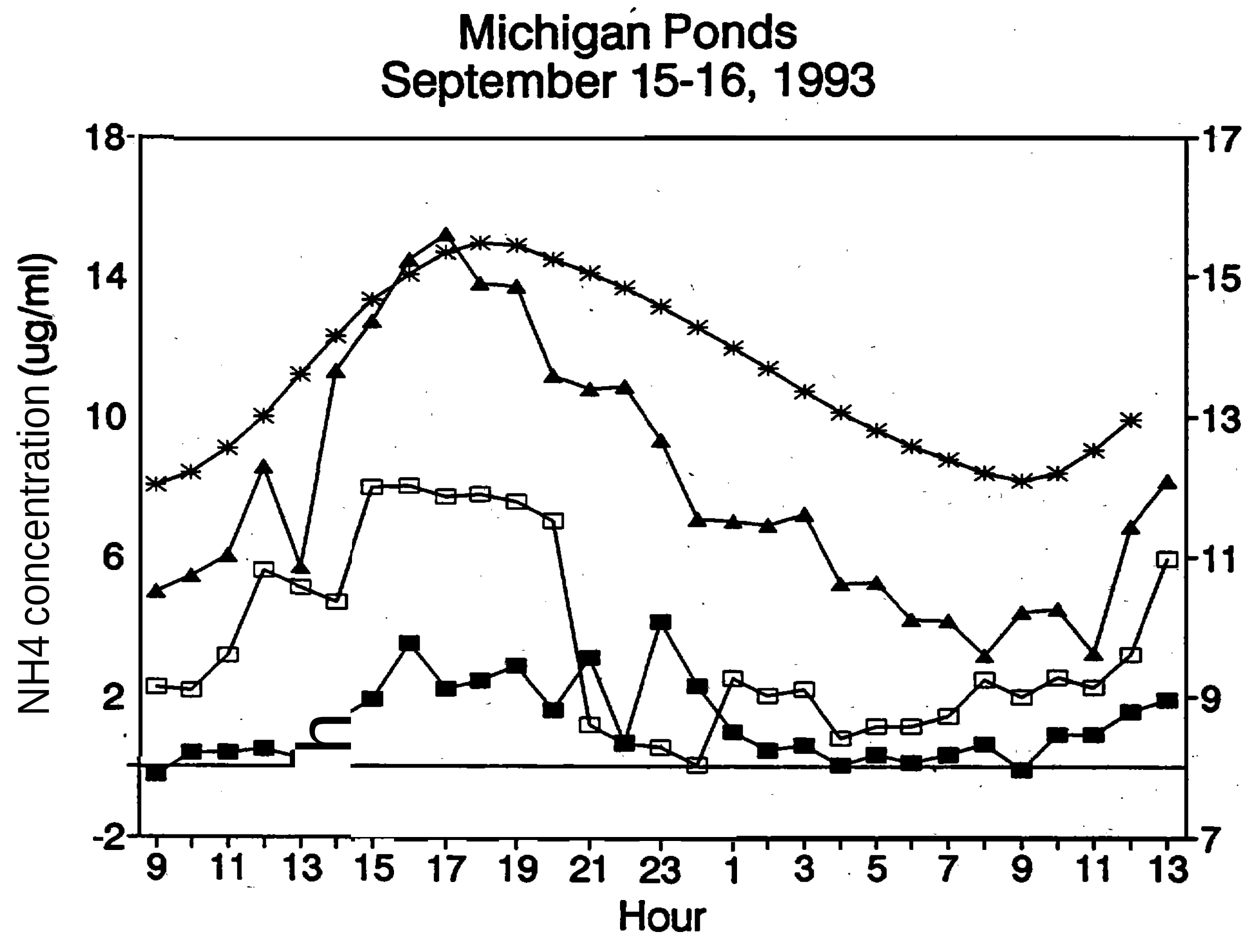
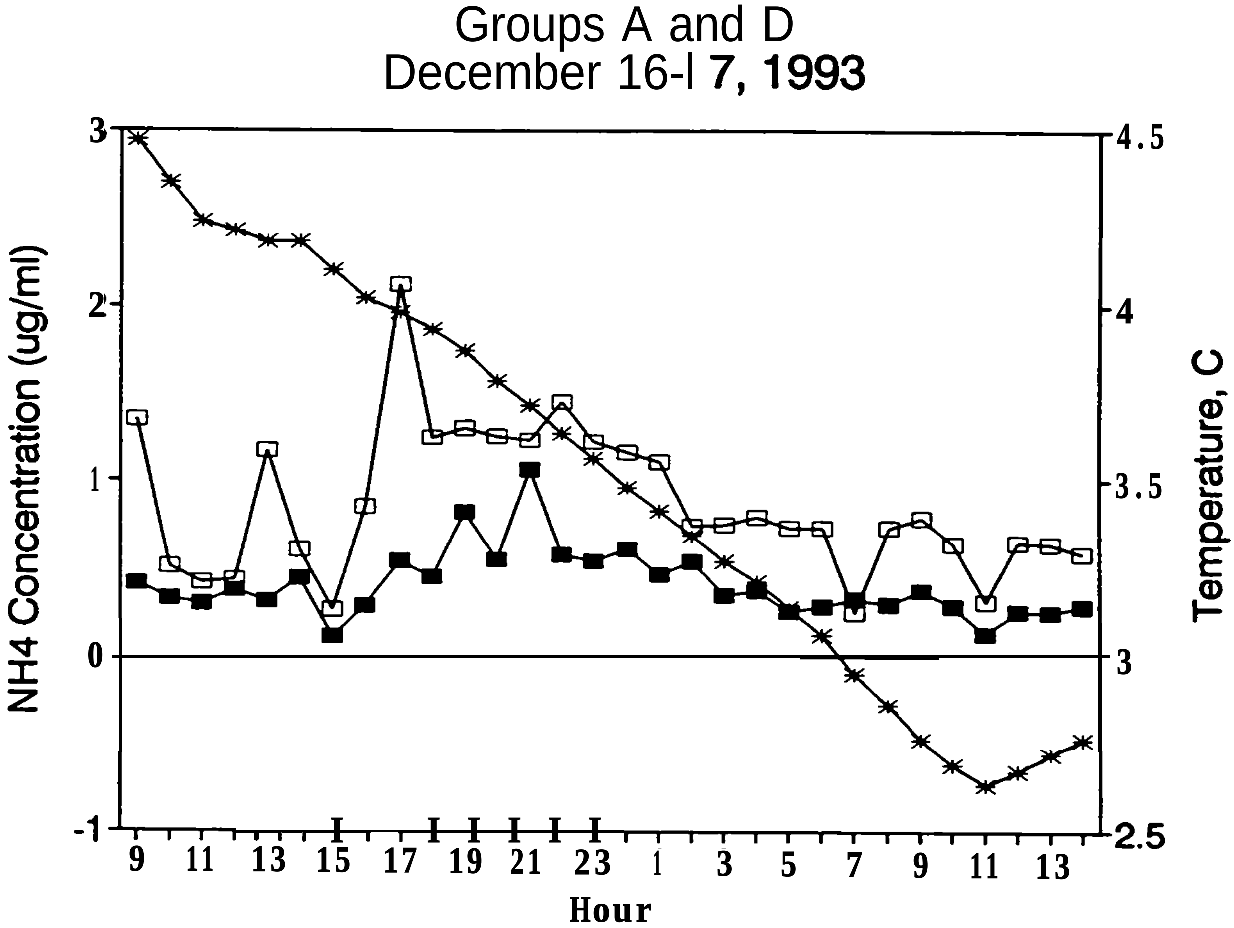


Fig. 13. Changes in ammonium ion concentration in the effluent from groups E (-■-), F (-□-), and G (-▲-) during hourly sampling from 15 September 1993 to 16 September 1993.



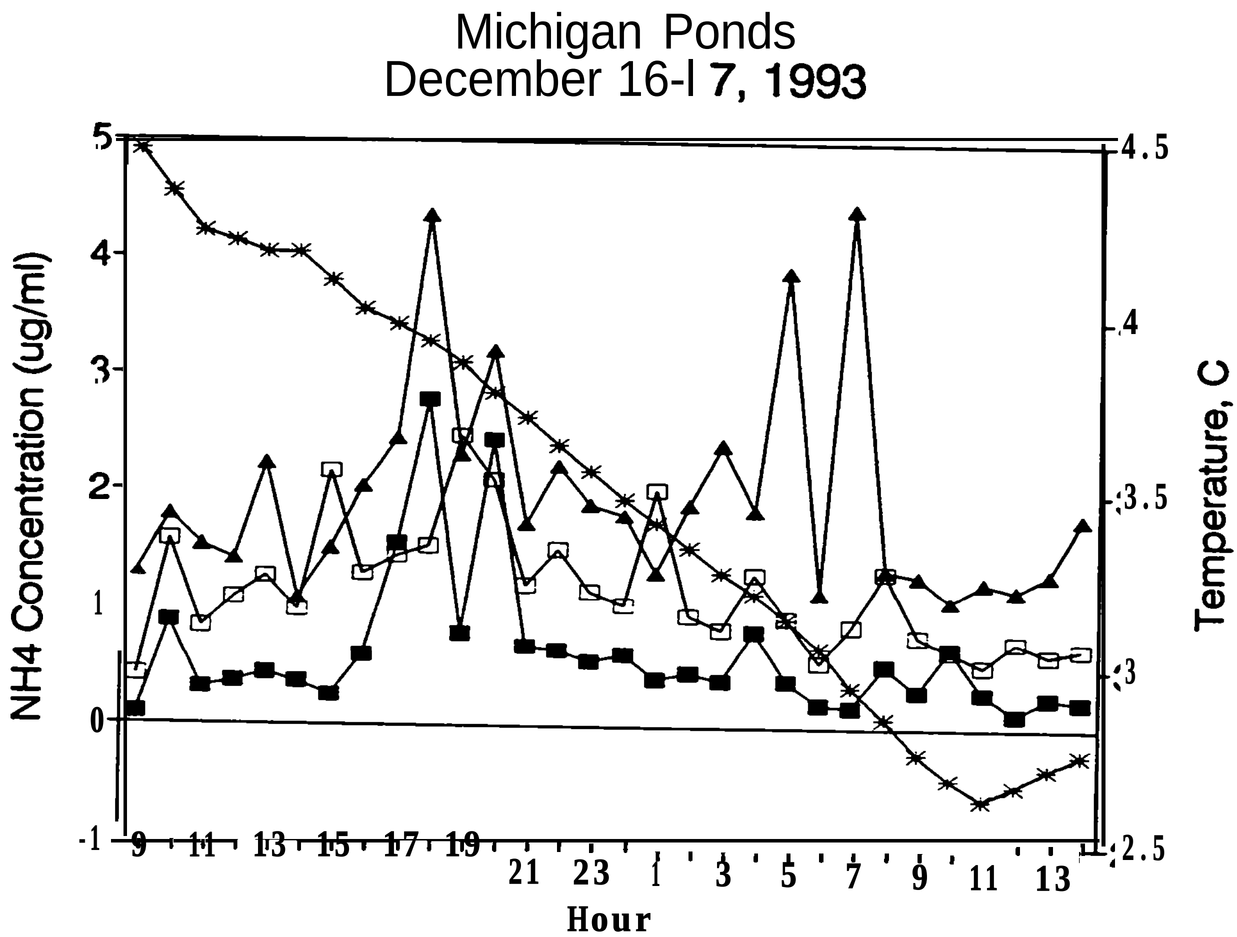
Michigan Ponds
September 15-16, 1993
NH4 concentration (ug/ml)
Hour
18
14
10
6
2
-2
17
15
13
11
9
7
9 11 13 15 17 19 21 23 1 3 5 7 9 11 13

fig. 14. Changes in ammonium ion concentration in the effluent from groups A (-■-) and D (-□-) during hourly sampling from 16 December 1993 to 17 December 1993.



Groups A and D
December 16-l 7, 1993
NH4 Concentration (ug/ml)
Temperature, C
3
2
1
0
-1
4.5
4
3.5
3
2.5
9
11
13
15
17
19
21
23
1
3
5
7
9
11
13
Hour

Fig. 15. Changes in ammonium ion concentration in the effluent from groups E (-I-), F (-□-), and G (-▲-) during hourly sampling from 16 December 1993 to 17 December 1993.



Michigan Ponds
December 16-17, 1993
NH4 Concentration (ug/ml)
Temperature, C
Hour
5
4
3
2
1
0
-1
4.5
4
3.5
3
2.5
9 11 13 15 17 19 21 23 1 3 5 7 9 11 13

metabolic parameters were evident, and ammonium ion production was reduced from the other two sampling periods. This may have been due to sampling the raceways during the two day period of fasting before transport and release.

Further analyses are being performed to determine the effects of density and oxygen supplementation on total nitrogen excretion. The results from these analyses will be described in future reports.

Solids

Weekly data for suspended solids is presented in Table 12. Data was averaged and data from replicate raceways were combined for analysis. Analysis of variance indicated a significant difference ($P \leq 0.05$) between groups (Figure 16). The amount of suspended solids entering the hatchery in the water ranged from 0.0 to 4.7 mg/l. An increase in suspended solids occurred with increased rainfall. During periods of rainfall, feeding of the fish is often curtailed because of "muddy" water.

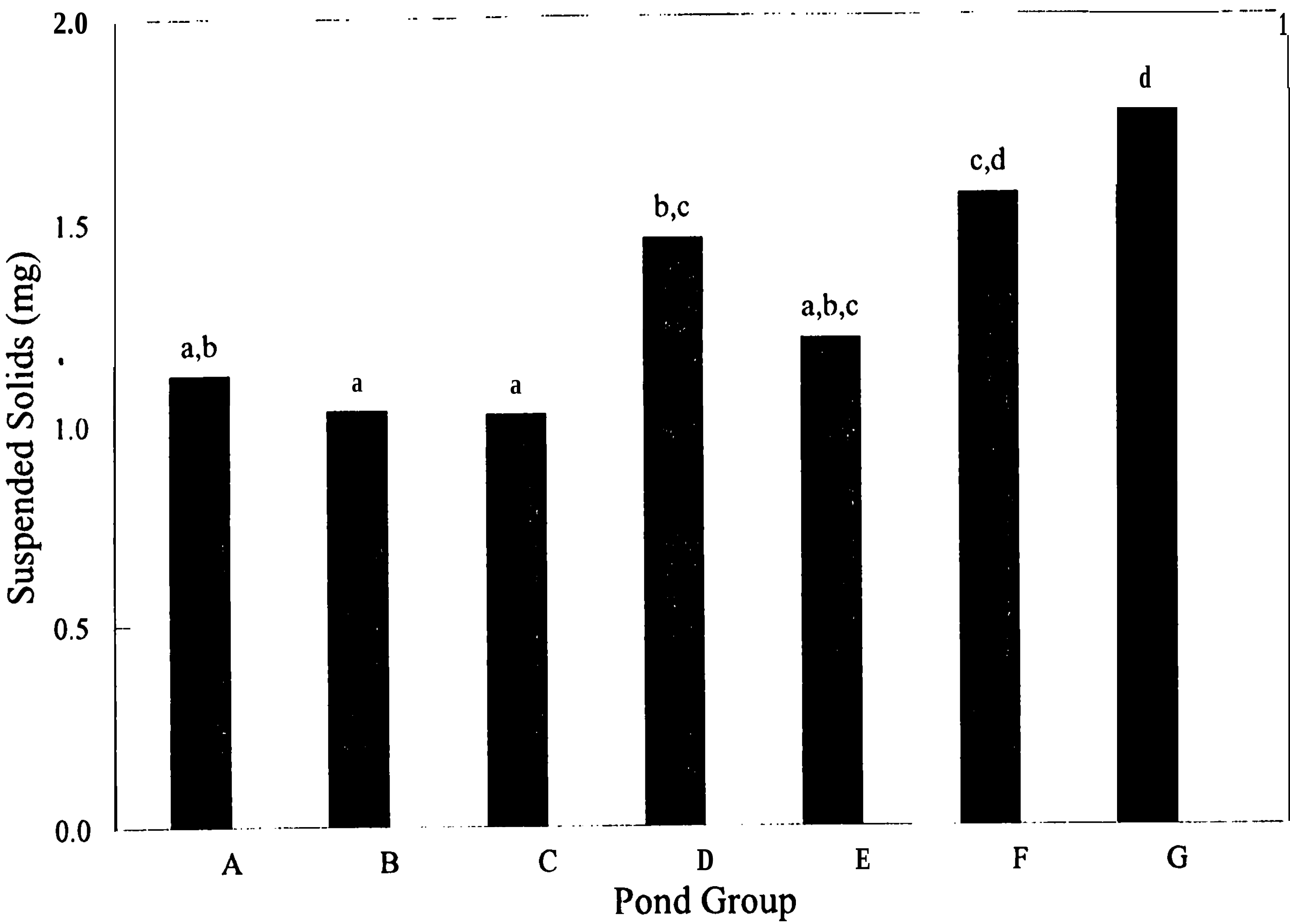
Table 12. Suspended solids (mg/L) at the inflow and outflow of various experimental ponds collected a8 single samples at Willamette Hatchery, 1993-1994.

Date	Inflow	Inflow	Al	A2	B1	B2	Cl	C2	D1	D2	Inflow	Inf Lou	El	E2	F1	F2	G1	G2
08/03/93	1.2		0.8		0.2		0.8		0.8		1.0		1.5		1.7		2.3	
08/05/93		1.2		0.8		0.8		1.3		1.5		1.5		2.2		1.7		2.5
08/10/93	1.7		0.8		1.0		0.7		1.2		1.2		1.0		1.8		2.5	
08/12/93		0.8		0.5		0.5		0.5		1.2		1.8		1.8		1.3		1.2
08/17/93	0.7		1.7		1.2		0.8		1.0		1.0		2.0		1.5		3.7	
08/19/93		1.0		1.0		0.8		0.5		2.5		1.5		2.5		4.2		3.7
08/24/93	0.8		0.2		0.7		0.7		0.8		0.8		0.7		0.7		2.2	
08/26/93		0.8		0.5		0.3		0.5		0.7		1.2		0.7		0.7		0.8
08/31/93	1.2		0.5		1.0		0.3		0.8		1.3		0.7		1.5		2.3	
09/02/93		0.5		0.8		1.7		0.8		1.2		1.3		1.0		1.3		1.3
09/07/93	0.7		3.7		1.2		0.5		1.2		0.8		1.0		1.2		2.2	
09/09/93		0.8		1.5		1.2		0.8		2.7		1.3		1.3		5.7		3.5
09/14/93	0.8		1.2		0.8		0.8		1.3		1.2		1.8		2.7		1.7	
09/16/93		0.5		1.0		1.0		0.8		2.5		1.2		1.0		2.2		2.3
09/21/93	1.3		0.5		0.3		0.5		1.0		0.7		0.8		0.7		1.0	
09/23/93		0.7		0.5		1.0		1.3		1.2		1.0		1.2		1.7		0.8
09/28/93	1.2		1.2		1.2		0.7		1.5		0.7		0.8		0.8		1.7	
09/30/93		0.2		0.0		0.8		1.7		1.5		1.0		0.7		1.5		1.7
10/05/93	0.7		0.7		0.3		0.7		2.3		0.7		1.2		1.7		2.3	
10/07/93		0.7		1.3		1.0		0.8		1.2		4.3		1.2		1.2		1.0
10/12/93	0.2		1.5		1.2		1.3		1.0		1.8		0.7		1.5		0.7	
10/14/93		0.7		0.8		0.3		0.7		2.3		1.3		1.3		0.8		1.5
10/19/93	0.7		0.5		0.7		0.5		0.8		1.2		0.8		0.7		0.8	
10/21/93		0.3		3.7		0.7		0.5		2.3		0.5		1.3		1.2		0.5
10/26/93	0.3		0.7		0.5		2.2		2.0		0.5		0.5		1.0		0.5	
10/28/93		1.2		0.3		0.7		0.7		1.0		0.8		0.8		0.7		3.0
11/02/93	0.5		0.8		0.3		0.7		0.7		0.7		0.8		0.8		1.0	
11/04/93		0.5		0.0		0.8		0.8		1.5		0.7		0.8		1.7		1.0
11/09/93	0.5		0.7		0.5		0.7		0.7		0.7		0.8		0.7		0.8	
11/11/93		0.5		0.3		0.3		0.5		0.3		0.3		0.5		0.8		1.8
11/16/93	0.7		0.5		0.0		0.8		4.3		0.8		0.5		0.8		0.5	
11/18/93		0.7		0.7		0.7		0.3		0.7		0.3		0.7		1.0		1.7
11/22/93	0.8		0.8		0.8		0.8		0.8		0.7		0.7		0.5		0.7	
11/24/93		0.2		0.7		0.7		0.5		0.7		0.3		0.7		0.7		0.5
11/30/93	1.0		2.0		1.8		1.5		1.7		1.2		1.5		1.7		1.8	

Table 12. Contcluded.

Date	Inflow	Inflow	A1	A2	B1	B2	C1	C2	D1	D2	Inflow	Inflow	E1	E2	F1	F2	G1	G2
12/02/93		3.7		3.0		4.2		2.7		2.7		3.2		2.7		3.3		2.8
12/08/93	4.7		3.8		4.0		5.3		6.3		4.3		4.0		5.7		6.5	
12/10/93		2.0		2.2		1.7		2.0		1.7		2.2		3.0		3.2		2.2
12/14/93	0.5		0.8		0.5		1.2		0.7		0.8		1.0		1.3		1.8	
12/16/93		0.7		1.3		0.8		1.0		1.3		1.0		1.5		1.3		1.2
12/21/93	- -		- -		- -		- -		- -		- -		- -		- -		- -	
12/23/93		- -		- -		- -		- -		- -		- -		- -		- -		- -
12/28/93	- -		- -		- -		- -		- -		- -		- -		- -		- -	
12/30/93		- -		- -		- -		- -		- -		- -		- -		- -		- -
01/04/94	- -		- -		- -		- -		- -		- -		- -		- -		- -	
01/06/94		- -		- -		- -		- -		- -		- -		- -		- -		- -
01/11/94	1.3		1.7		1.7		2.0		2.2		1.8		2.0		2.2		1.5	
01/13/94		0.8		2.3		2.0		1.5		2.0		1.7		1.8		2.5		3.2
01/18/94	0.5		0.8		1.5		1.0		1.0		0.8		1.7		1.2		1.7	
01/20/94		1.0		1.0		4.5		1.5		1.3		1.2		1.5		1.7		1.5
01/25/94	0.8		1.3		0.5		1.5		1.0		0.8		0.8		0.7		0.5	
01/27/94		0.8		1.0		2.2		0.8		1.3		1.5		1.2		1.3		1.2
02/01/94	0.7		1.3		0.3		1.2		1.3		0.2		0.2		1.0		4.5	
02/03/94		1.2		0.7		0.5		0.0		0.3		0.0		1.2		0.7		0.3
02/08/94	0.3		0.3		0.3		1.8		1.3		0.8		0.5		1.0		1.7	
02/10/94		0.2		0.0		0.2		0.2		0.5		0.0		0.5		0.2		0.3
02/15/94	1.0		1.2		0.8		0.5		0.8		1.0		1.0		1.2		1.3	
02/17/94		1.0		1.5		1.2		1.0		1.2		0.8		1.0		3.0		2.0

Fig. 16. Average suspended solids (mg/L) for various experimental raceways at Willamette Hatchery, 1993-1994. Suspended solids were averaged over the rearing period. Values from replicate groups were combined. Bars with the same small superscript letter are not significantly different ($P < 0.05$).



Suspended Solids (mg)
2.0
1.5
1.0
0.5
0.0
a,b
a
a
b,c
a,b,c
c,d
d
A
B
C
D
E
F
G
Pond Group

Fish Culture

Liberation Data

Liberation data for various experimental groups are shown in Tables 13 and 14. Total numbers of fish released were different by the two accounting methods of pond inventories and water displacement in liberation trucks. In general, numbers estimated from liberation truck displacements were lower than those estimated from pond inventories and mortality counts. Similar differences between the two inventory methods were observed in past years (Ewing and Sheahan 1991, 1992). In the previous annual reports, we described unaccounted losses in all ponds that varied from -1.6% to 27.1% of the initial populations in the ponds. We suggested that errors in population estimates from fish displacement in the liberation trucks could account for these unexplained losses (Ewing et al. 1994). An alternative source of error in the population estimates could result from a high level of avian predation.

Predation during the 1991-1992 rearing cycle was thought to be insignificant as a source of error in population estimates but during the 1993-1994 rearing cycle as many as 40 great blue herons were observed around the raceways containing experimental fish. Predation undoubtedly contributes to the unexplained fish loss. However, losses in pond groups Al (1.04%), B_1 (4.02%), Cl (6.94%), and D_1 (0.13%) are difficult to explain by predation.

Table 13. Data at liberation for 1992-brood spring chinook salmon released from Willamette Hatchery in February 1994.

Group	Tag code	Number tagged	Inven- tory	Total liberation	Fish/ Kg	Fish loss (percent)	Final load lbs/gpm	Final density lbs/ft3
A1				38955	34.9	1.04%	4.91	0.66
A2	07-63-23 07-63-22	32358 32055	39364 39273	36525	33.1	7.00%	4.86	0.66
Average				34.0	4.02%	4.89	0.66	
B1	07-63-37	20106	19950	17550	29.7	12.03%		0.35
B2	07-63-36	20140	19759	17550	28.6	11.18%	5.- E	0.37
Average				29.1	11.60%	2.65	0.36	
C1	07-63-24	32070	39442	36704	32.5	6.94%	4.96	0.67
C2	07-63-25	31981	38655	33082	30.6	14.42%	4.76	0.64
Average				31.5	10.68%	4.86	0.66	
D1	07-63-26	32037	116264	116110	37.4	0.13%	13.66	1.85
D2	07-63-27	32046	116180	108378	35.7	6.72%	13.36	1.81
Average				36.5	3.42%	13.51	1.83	
E1	07-63-28	32049	59296	44505	47.3	24.94%	2.76	1.12
E2	07-01-28	32000	58878	41760	38.2	29.07%	3.20	1.30
Average				42.8	27.01%	2.98	1.21	
F1	07-01-29	32000	58684	50460	38.3	14.01%	3.87	1.57
F2	07-01-30	32031	58893	49077	37.6	16.67%	3.83	1.55
Average				37.9	15.34%	3.85	1.56	
G1	07-01-31	32060	59340	53235	37.2	10.29%	4.20	1.70
G2	07-01-32	32119	59492	51136	41.3	14.05%	3.63	1.47
Average				39.2	12.17%	3.92	1.59	
Dexter	07-01-33	32000		154364	16.9		1.63	0.37
	07-07-34	31892		154363	16.9		1.63	0.37

Table 14. Weights, lengths and condition factor (K) for 1992-brood spring chinook salmon released from Willamette Hatchery in February 1994.

Group	July			October			December			February		
	grams	mm	Condition factor 10^7	grams	mm	Condition factor X10^7	grams	mm	Condition factor X10^7	grams	mm	Condition factor X10^7
A1	6.7	81.6	123.75	24.8	115.0	163.14	27.7	130.0	126.27	28.7	135.9	114.20
A2	6.8	81.1	127.80	29.3	122.3	160.08	26.9	134.1	111.53	30.3	140.2	109.89
B1	6.4	80.1	123.66	27.3	119.6	159.51	30.5	138.9	113.79	33.7	138.8	126.05
B2	6.0	80.2	116.87	26.7	125.7	134.29	31.3	140.8	112.38	35.0	147.2	109.80
C1	6.5	83.6	110.84	28.0	116.6	176.57	27.9	133.6	116.92	30.7	138.6	115.33
C2	6.7	82.1	120.65	26.4	119.9	153.00	29.9	135.0	121.60	32.7	140.8	117.31
D1	5.7	81.5	106.02	24.5	108.6	191.56	24.4	123.6	129.47	26.7	133.5	112.29
D2	6.1	81.9	110.94	27.1	115.3	176.45	26.3	132.4	113.27	28.0	135.6	112.30
E1	6.3	83.2	109.44	20.7	111.1	151.18	19.3	123.2	103.38	21.1	126.5	104.35
E2	6.7	81.0	126.18	22.1	118.7	132.43	24.2	129.1	112.31	26.2	131.3	115.52
F1	6.7	80.7	126.97	24.9	116.6	157.19	28.6	132.4	123.18	26.1	132.5	112.46
F2	6.4	81.5	119.18	23.1	116.7	145.15	22.7	130.1	103.16	26.6	130.5	119.58
G1	6.1	81.1	114.37	22.1	114.2	148.42	24.1	130.9	107.15	26.9	131.8	117.42
G2	5.9	80.8	111.38	22.5	110.4	166.76	21.3	121.5	119.01	24.2	127.8	116.05

Groups A1 and C1 are next to each other and have the same numbers of fish. Group C1 differs from group A1 only by the presence of an oxygen contact column at the head end of the pond. Also, predation should occur to a greater extent in ponds containing higher numbers of fish, but the degree of loss in group B1, which has the least number of fish per pond, was higher than that of group D_1, which had nearly six times as many fish. This suggests that regardless of the large number of herons observed, the greatest source of error in population estimates comes from either measurements of fish size or water displacement in the liberation trucks.

A significant difference ($P \leq 0.05$) in fish weight at release was observed between the groups (Fig. 17). This result was not desirable because changes in fish size at release can affect the subsequent survival of the juveniles to adulthood (Johnson 1970; Hagar and Noble 1976; Reisenbichler et al. 1982). These differences in fish size affected the final densities and loads. All groups were less than originally projected due to the smaller size of fish (Table 15).

Mortalities for all ponds were low and similar throughout the year (Table 16). A sample of 20 fish was taken from each pond just prior to release to obtain a level of BKD as determined by enzyme linked immunosorbent assay (ELISA) (Appendix C). Optical densities of less than ,100 were classified as non-detectable because of background interference. Low, medium, high levels of BKD were defined by ranges of optical densities of 0.100-0.199, 0.200-0.499 and greater than 0.499, respectively.

Fig. 17. Average weight at release of juvenile chinook salmon from experimental ponds at Willamette Hatchery, 1994.

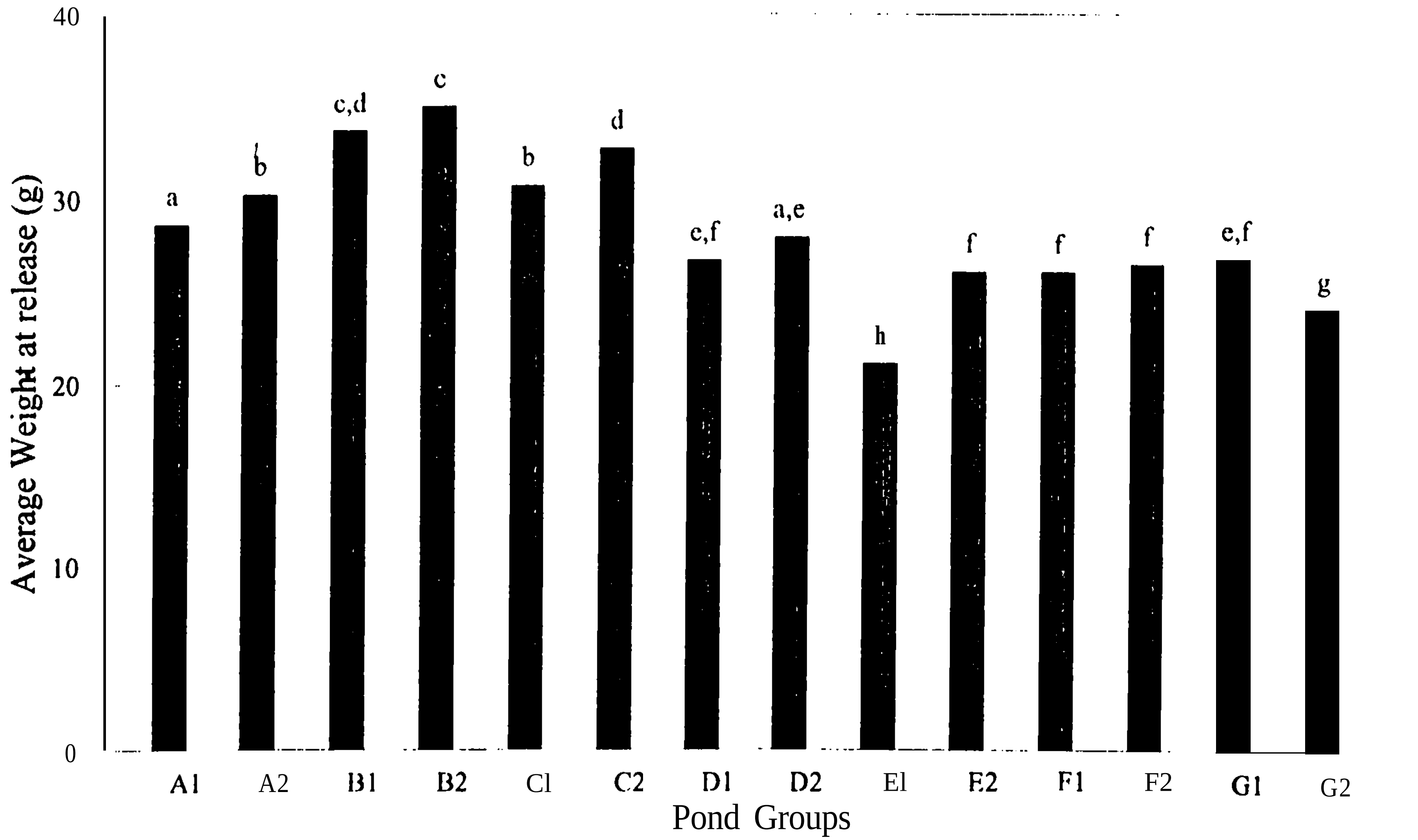

40
30
20
10
0
Average Weight at release (g)
a
b
c,d
c
b
d
e,f
a,e
h
f
f
f
e,f
g
A1
A2
B1
B2
C1
C2
D1
D2
E1
E2
F1
F2
G1
G2
Pond Groups

Table 15. Comparison between ideal experimental conditions listed in Table 2 and actual loads and densities at the time of release of experimental groups of spring chinook salmon from Willamette Hatchery on 28 February 1994.

Group	Density (pounds/cubic foot) Ideal	Density (pounds/cubic foot) Actual	Load (pounds/gallon/minute) Ideal	Load (pounds/gallon/minute) Actual
Al	0.97	0.66	7.20	4.91
A2		0.66		4.86
81	0.49	0.35	3.60	2.60
82		0.37		2.70
C1				
C2	0.97	0.64 0.67	7.20	4.96
				3.18
D1				
D2	2.92	1.85 1.81	21.60	13.66
				13.36
E1				
E2	2.92	1.30 1.12	7.20	2.76
				3.20
F1	2.92	1.57	7.20	3.87
F2		1.55		3.83
G1				
G2	2.92	1.70 1.47	7.20	4.20
				3.63

Table 16. Observed mortality recorded by month and group of juvenile spring chinook salmon reared in experimental ponds at Willamette Hatchery, 1993-1994[a].

Group	Aug	Sep	Oct	Nov	Dec	Jan	Feb
A1	56	39	32	18	12	55	43
A2	61	24	46	48	31	31	58
81	34	10	20	23	13	18	38
B2	44	36	29	31	30	28	55
C1	33	20	34	33	19	31	33
c2	72	51	27		47	32	51
D1	170	66	100	1::	77	87	91
D2	196	140	100	120	61	61	106
El	70	62	57	31	29	26	50
E2	10	17	31	15	16	9	48
F1	64	29	55	46	40	44	63
F2	32	13	28	13	19	16	41
G1	44	29	59	30	35	35	72
G2	66	9	59	22	25	18	49

[a] Fifteen fish were sacrificed each month for smolt quality assays from pond A2, B2, C2, D2, El, Fl, and Gl.

The percentage of the fish sampled in each of the low, medium and high groups is shown in Table 17. Fish from pond B_2 had the highest mean optical density and were significantly different (Fisher's LSD $P<.05$) from those of all other groups except E_1 and A_1. Group E_1 was significantly different (Fisher's LSD $P<.05$) than group B_1. Tests conducted on the fish released in 1993 showed 5 groups of fish measuring in the high range and 7 groups in the medium range whereas the 1994 tests showed no groups in the high range and 8 groups in the medium range. The levels of BKD may affect the survival so that a comparison of the replicates should be done to determine if the levels of BKD rather than treatment groups have a higher impact on total returns.

Condition factors of fish at release were not significantly different ($P \leq 0.05$) (Table 14).

Growth

Fish were ponded in experimental raceways after tagging from 6 July 1993 to 27 July 1993. Starting weights and numbers are shown in Table 18.

Monthly growth of the fish was measured in three different ways (Ricker 1975). Absolute growth is shown in Table 19, relative growth is shown in Table 20, and instantaneous growth rate is given in Table 21. The large variations in growth between months resulted from a lack of precision in the pond counts. From work performed at this and other hatcheries (Ewing

Table 17. Mean optical density of groups of fish tested for BKD by ELISA and the percentage of fish that contained non-detectable, low, medium, and high levels of BKD. Non detectable levels are defined as optical densities less than 0.100. Low, medium, and high levels are defined as optical densities of 0.100-0.199, 0.200--499 and greater than .499, respectively.

	Mean Optical Density	Percentage in category			
		Non detectable	Low	Medium	High
A1	0.114	65.0%	25.0%	10.0%	0.0%
A2	0.113	45.0%	55.0%	0.0%	0.0%
B1	0.093	85.0%	15.0%	0.0%	0.0%
B2	0.139	45.0%	45.0%	10.0%	0.0%
Cl	0.112	40.0%	60.0%	0.0%	0.0%
C2	0.108	45.0%	55.0%	0.0%	0.0%
D1	0.104	50.0%	50.0%	0.0%	0.0%
D2	0.097	66.7%	28.6%	4.8%	0.0%
E1	0.120	50.0%	40.0%	10.0%	0.0%
E2	0.101	55.0%	40.0%	5.0%	0.0%
F1	0.102	65.0%	30.0%	5.0%	0.0%
F2	0.098	71.4%	28.6%	0.0%	0.0%
G1	0.108	70.0%	25.0%	5.0%	0.0%
G2	0.111	60.0%	35.0%	5.0%	0.0%

Table 18. Starting weights and numbers for juvenile spring chinook salmon introduced into experimental ponds in July 1993 at Willamette **Hatchery.**

	Number/kg	Total Weight **(kg)**	**Number**
A1 A2	148.9 147.0	266.0 269.3	39619 39572
B1 B2	157.1 165.7	120.8 128.0	20106 20012
C1 C2	154.4 149.8	256.7 260.2	39645 38976
D1 D2	174.0 164.3	672.2 711.7	116964 116978
E1 E2	149.2 158.4	376.4 395.7	59621 59024
F1 F2	150.0 155.1	393.4 380.8	59025 59055
G1 G2	163.7 170.3	364.4 350.8	59644 59740

Table 19. Absolute change in weight in grams per month for spring chinook salmon reared in experimental raceways at Willamette Hatchery, 1993-1994.

Group	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Overall
A1	4.5	8.0	5.6	-2.5	5.4	-0.2	1.1	21.9
A2	5.9	9.0	7.5	-0.7	-1.7	1.0	2.4	23.4
	5.2	8.5	6.6	-1.6	1.9	0.4	1.7	22.7
B1	4.9	9.8	6.2	0.4	2.8	2.0	1.2	27.3
B2	5.6	13.9	1.1	0.9	3.8	0.9	2.8	29.0
	5.3	11.8	3.7	0.7	3.3	1.4	2.0	28.2
C1	3.8	9.5	8.3	-0.9	0.8	5.5	-2.7	24.3
C2	5.0	10.4	4.4	0.2	3.3	0.8	2.0	26.1
	4.4	9.9	6.3	-0.4	2.1	3.2	-0.3	25.2
D1	3.1	8.0	7.7	-2.0	1.9	2.6	-0.3	21.0
D2	4.8	8.4	7.7	-1.1	0.3	2.3	-0.6	21.9
	3.9	8.2	7.7	-1.5	1.1	2.5	-0.4	21.5
E1	3.7	6.3	4.4	2.0	-3.4	0.9	0.9	14.8
E2	4.7	7.0	3.7	-1.7	3.8	5.0	-3.0	19.5
	4.2	6.7	4.0	0.1	0.2	3.0	-1.1	17.1
F1	5.0	7.6	5.7	1.3	2.3	-3.9	1.4	19.5
F2	4.7	8.5	3.4	0.7	-1.1	8.8	-5.0	20.1
	4.9	8.0	4.6	1.0	0.6	2.5	-1.8	19.8
G1	3.9	7.3	4.8	-0.1	2.1	4.4	-1.5	20.8
G2	3.4	7.7	5.5	0.4	-1.5	2.7	0.2	18.4
	3.7	7.5	5.1	0.1	0.3	3.5	-0.7	19.6

Table 20. Relative change in weight in grams per month for spring chinook salmon reared in experimental raceways at Yillamette Hatchery, 1993-1994.

Group	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Overall
A1	0.67	0.72	0.29	-0.10	0.24	-0.01	0.04	3.27
A2	0.87	0.71	0.35	-0.02	-0.06	0.04	0.08	3.45
	0.77	0.71	0.32	-0.06	0.09	0.02	0.06	3.36
B1		0.87	0.29	0.02	0.10	0.06	0.04	4.29
B2	0.7..94	1.19	0.04	0.03	0.14	0.03	0.09	4.80
	0.86	1.03	0.17	0.02	0.12	0.05	0.06	4.55
C1		0.92	0.42	-0.03	0.03	0.20	-0.08	3.75
C2	0.58 0.75	0.89	0.20	0.01	0.13	0.03	0.07	3.90
	0.67	0.91	0.31	-0.01	0.08	0.11	-0.01	3.82
D1								
D2	0.79 0.54	0.90	0.46	-0.08	0.09	0.11	-0.01	3.65
		0.77	0.40	-0.04	0.01	0.09	-0.02	3.60
	0.66	0.84	0.43	-0.06	0.05	0.10	-0.02	3.63
E1		0.63	0.27	0.10	-0.15	0.05	0.04	2.35
E2	0.59 0.71	0.61	0.20	-0.08	0.19	0.21	-0.10	2.90
	0.65	0.62	0.23	0.01	0.02	0.13	-0.03	2.63
F1	0.75	0.65	0.30	0.05	0.09	-0.14	0.06	2.92
F2	0.73	0.76	0.18	0.03	-0.04	0.39	-0.16	3.12
	0.74	0.70	0.24	0.04	0.02	0.13	-0.05	3.02
G1	0.64	0.72	0.28	-0.01	0.10	0.18	-0.05	3.40
G2	0.59	0.83	0.32	0.02	-0.07	0.13	0.01	3.13
	0.61	0.77	0.30	0.01	0.01	0.15	-0.02	3.26

Table 21. Instantaneous change in weight in grams per month for spring chinook salmon reared in experimental raceways at Willamette Hatchery, 1993-1994.

Group	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Overall
A1		0.54	0.26	-0.11	0.22	-0.01	0.04	1.45
A2	0.51 0.63	0.54	0.30	-0.02	-0.06	0.04	0.08	1.49
	0.57	0.54	0.28	-0.07	0.08	0.02	0.06	1.47
B1	0.57	0.62	0.26	0.02	0.10	0.06	0.04	1.67
B2	0.66	0.78	0.04	0.03	0.13	0.03	0.08	1.76
	0.62	0.70	0.15	0.02	0.11	0.05	0.06	1.71
Cl	0.46	0.65	0.35	-0.03	0.03	0.18	-0.08	1.56
c2	-0.56	0.64	0.18	0.01	0.12	0.03	0.06	1.59
	0.51	0.64	0.27	-0.01	0.07	0.10	-0.01	1.57
D1	0.43	0.64	0.38	-0.09	0.08	0.10	-0.01	1.54
D2	0.58	0.57	0.34	-0.04	0.01	0.08	-0.02	1.53
	0.51	0.61	0.36	-0.06	0.05	0.09	-0.02	1.53
El	0.47	0.49	0.24	0.09	-0.16	0.05	0.04	1.21
E2	0.54	0.48	0.18	-0.08	0.17	0.19	-0.11	1.36
	0.50	0.48	0.21	0.00	0.00	0.12	-0.03	1.29
F1		0.50	0.26	0.05	0.08	-0.15	0.06	1.37
F2	0.56 0.55	0.57	0.16	0.03	-0.05	0.33	-0.17	1.42
	0.55	0.53	0.21	0.04	0.02	0.09	-0.06	1.39
G1		0.54	0.25	-0.01	0.09	0.17	-0.06	1.48
G2	0.50 0.46	0.60	0.28	0.02	-0.07	0.12	0.01	1.42
	0.48	0.57	0.26	0.01	0.01	0.14	-0.02	1.45

et al. 1993), it may not be possible to achieve a level of precision in pond counts sufficient to provide accurate monthly growth rates. The difference between the initial weight at ponding and final weight at liberation may therefore provide a better comparison between raceways than a month-by-month comparison.

Growth rates were estimated from the initial weights at ponding and final weights at liberation (Tables 22, 23, and 24). Analysis of the growth rates over four years of experimental rearing showed no significant difference (analysis of variance $P \leq .05$) between any of the groups when the instantaneous rates were compared. There were differences in the relative rate (Fig. 18) and a greater detectable difference in the absolute rate (Fig. 19). Fish reared in the Michigan style ponds (Groups E, F, G) showed the slowest rate of gain with the first pass (E) being lowest,

Monthly food conversions for each experimental pond are shown in Table 25. The large variations and negative values resulted from lack of precision in the pond counts. Monthly food conversions are therefore probably of little value unless the error in determining pond counts can be reduced. This problem is greater in the winter months when cold temperatures can result in negative weight gains for the fish. Overall food conversions are probably of greater importance to this study. Overall weight gain and feed conversions for the four rearing cycles are compared in Table 26. When the overall feed conversions were combined for all years, analysis of variance ($P \leq .05$) showed

Table 22. Absolute change in weight in grams for the entire experimental rearing period at Uillamette Hatchery, 1990-1994.

Group	1990-1991	1991-1992	1992-1993	1993 1994	Average
Al	27.8	35.3	39.0	21.9	
A2	23.0	34.6	38.8	23.4	30.5
B1	32.0	41.3	39.4	27.3	
B2	25.6	34.2	37.0	29.0	33.2
C1	28.1	37.3	44.3	24.3	
C2	28.7	31.8	38.4	26.1	32.4
D1	20.0	30.2	37.7	21.0	
D2	22.8	27.1	36.6	21.9	27.2
E1	17.2	18.4	26.3	14.8	
E2	19.0	20.3	24.9	19.5	20.1
F1	20.1	24.5	27.7	19.5	
F2	21.0	25.7	27.8	20.1	23.3
G1	19.7	26.7	30.1	20.8	
G2	20.5	25.7	25.6	18.4	23.4

Table 23. Relative change in weight in grams for the entire experimental rearing period at Uillamette Hatchery, 1990-1994.

Group	1990- 1991	1991-1992	1992-1993	1993- 1994	Average
A1					
A2	2.09 1.48	3.51 4.19	3.85 4.26	3.27 3.45	3.26
B1					
B2	2.18 1.63	4.81 3.69	3.65 3.60	4.29 4.80	3.58
C1					
C2	2.00 2.05	4.84 3.78	4.59 3.75	3.75 3.90	3.58
D1	1.73	4.45	3.57	3.65	
D2	1.55	3.75	3.43	3.60	3.22
E1					
E2	1.77 1.48	2.37 1.90	2.36 2.49	2.35 2.90	2.20
F1	1.55	2.75	2.69	2.92	
F2	1.71	2.88	3.15	3.12	2.60
G1	1.81	2.52	3.22	3.40	
G2	1.77	2.83	2.75	3.13	2.68

Table 24. Instantaneous change in weight in grams for the entire experimental rearing period at Uillamette Hatchery, 1990-1994.

Group	1990-1991	1991-1992	1992-1993	1993-1994	Average
Al	1.13	0.71	0.71	1.45	
A2	0.91	0.65	0.72	1.49	0.97
B1	1.16	0.76	0.67	1.67	
B2	0.97	0.67	0.66	1.76	1.04
Cl	1.10	0.77	0.75	1.56	
c2	1.11	0.68	0.68	1.59	1.03
Dl	1.00	0.74	0.66	1.54	
D2	0.94	0.68	0.65	1.53	0.97
E1	0.91	0.46	0.53	1.21	
E2	1.02	0.53	0.54	1.36	0.82
Fl	0.94	0.57	0.57	1.37	
F2	1.00	0.59	0.62	1.42	0.88
Gl	1.03	0.66	0.63	1.48	
G2	1.02	0.58	0.57	1.42	0.92

Fig. 18. Average relative growth rates for chinook salmon reared under experimental conditions at Willamette Hatchery, 1990-1994.

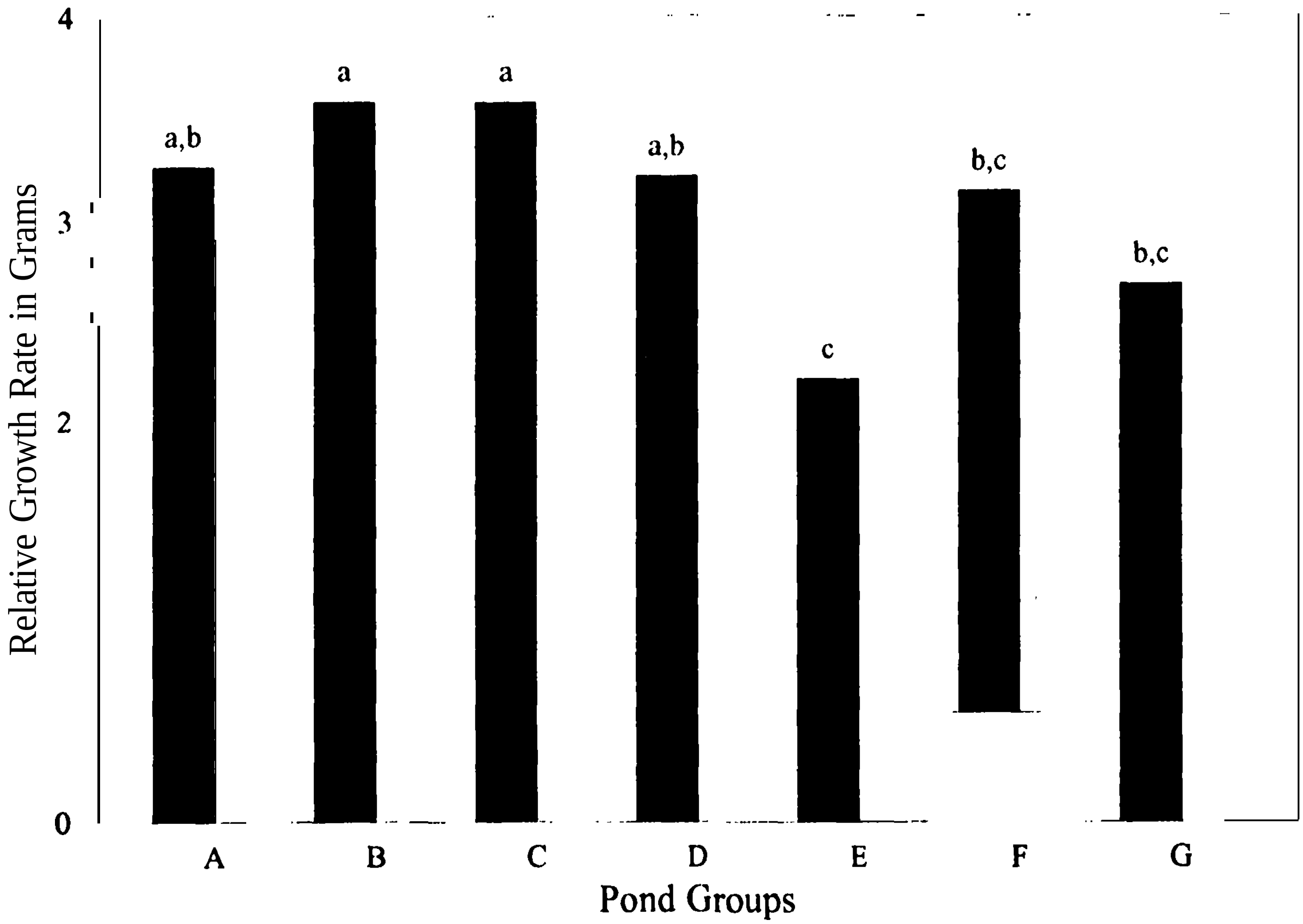
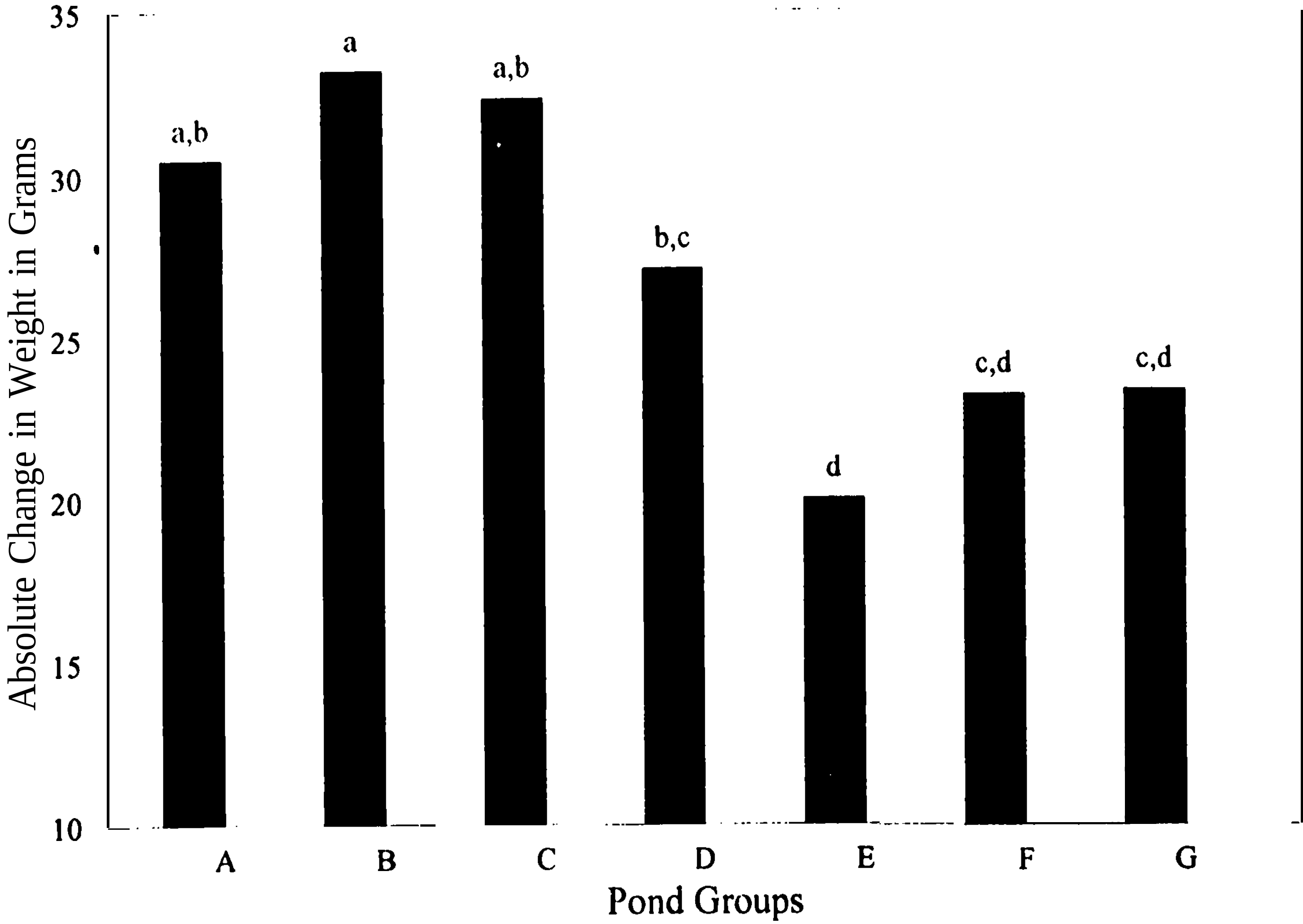

4
3
2
0
Relative Growth Rate in Grams
a,b
a
a
a,b
c
b,c
b,c
A
B
C
D
E
F
G
Pond Groups

Fig. 19. Average absolute growth rates for chinook salmon reared under experimental conditions at Willamette Hatchery, 1990-1994..



35
30
25
20
15
10
Absolute Change in Weight in Grams
a,b
a
a,b
b,c
d
c,d
c,d
A
B
C
D
E
F
G
Pond Groups

Table 25. Food conversion of spring chinook salmon reared in experimental raceways at Willamette Hatchery, 1993-1994.

Group	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Al	1.84	1.48	2.00	-1.54	0.41	-13.84	0.32
A2	1.74	1.27	1.27	-5.27	-1.67	3.85	0.07
81	1.68	1.30	1.92	11.45	1.02	1.85	-1.06
82	2.12	0.93	6.90	5.99	0.98	5.59	-0.37
C2	2.32	1.34	1.31	-3.70	3.21	0.69	-1.71
D1	2.28 1.92	1.31 1.21	2.18 1.28	24.43 -1.45	0.81	4.74	-0.91
					1.11	1.19	-0.17
E1	1.64	1.29	1.27	-2.56	6.95	1.35	-1.09
E2	1.60 1.81	1.31 1.19	2.03 1.56	-1.12 0.88	-0.50	2.55	-2.57
					0.48	0.53	-5.45
F2	1.58	1.25	1.45	1.57	0.76	-0.65	-1.21
G1	1.45 1.67	1.06 1.26	2.26 1.65	-15.19 3.12	-1.67	0.29	-4.87
					0.89	0.60	-2.15
G2	1.78	1.12	1.41	5.67	-1.15	0.96	-1.66

Large numbers, extreme variability, and negative numbers resulted trom the lack of precision in pond counts (see Tables 19-21).

Table 26. Overall feed conversion by group for rearing years 1990-1991, 1991-1992, 1992-1993, and 1993-1994 at Willamette Hatchery.

Group	1990-1991	1991-1992	1992-1993	1993-1994	Average
Al	1.70	1.69	1.61	1.98	
A2	2.13	1.77	1.69	2.10	1.83
B2	1.57	1.72	1.56	2.01	
C1	2.22 1.72	1.80 1.78	1.70 1.36	2.04 1.97	1.82
C2	1.60	2.04	1.56	2.11	1.78
D1					
D2	1.60 1.70	1.70 1.59	1.72 1.76	1.81 1.94	1.73
E1					
E2	2.11 1.77	2.15 2.34	2.93 2.96	3.10 2.68	2.50
F1					
F2	1.93 1.71	2.09 1.89	2.20 2.21	2.15 2.05	2.03
G1			1.88		
G2	1.93 1.90	1.89 1.90	2.47	2.07 1.81	1.98

that group E was significantly higher than all the other groups while group F was also significantly higher than group D (Fig. 20). The higher flows in the Michigan style ponds and extra flow required to balance the pumps in subsequent ponds may increase the food conversion rate by requiring more energy to maintain their position in the water column. The substantial loss recorded at liberation from group E also raised the food conversion of this group. Also, the increased predation suspected for the Michigan style ponds may result in lower rates of growth and conversion.

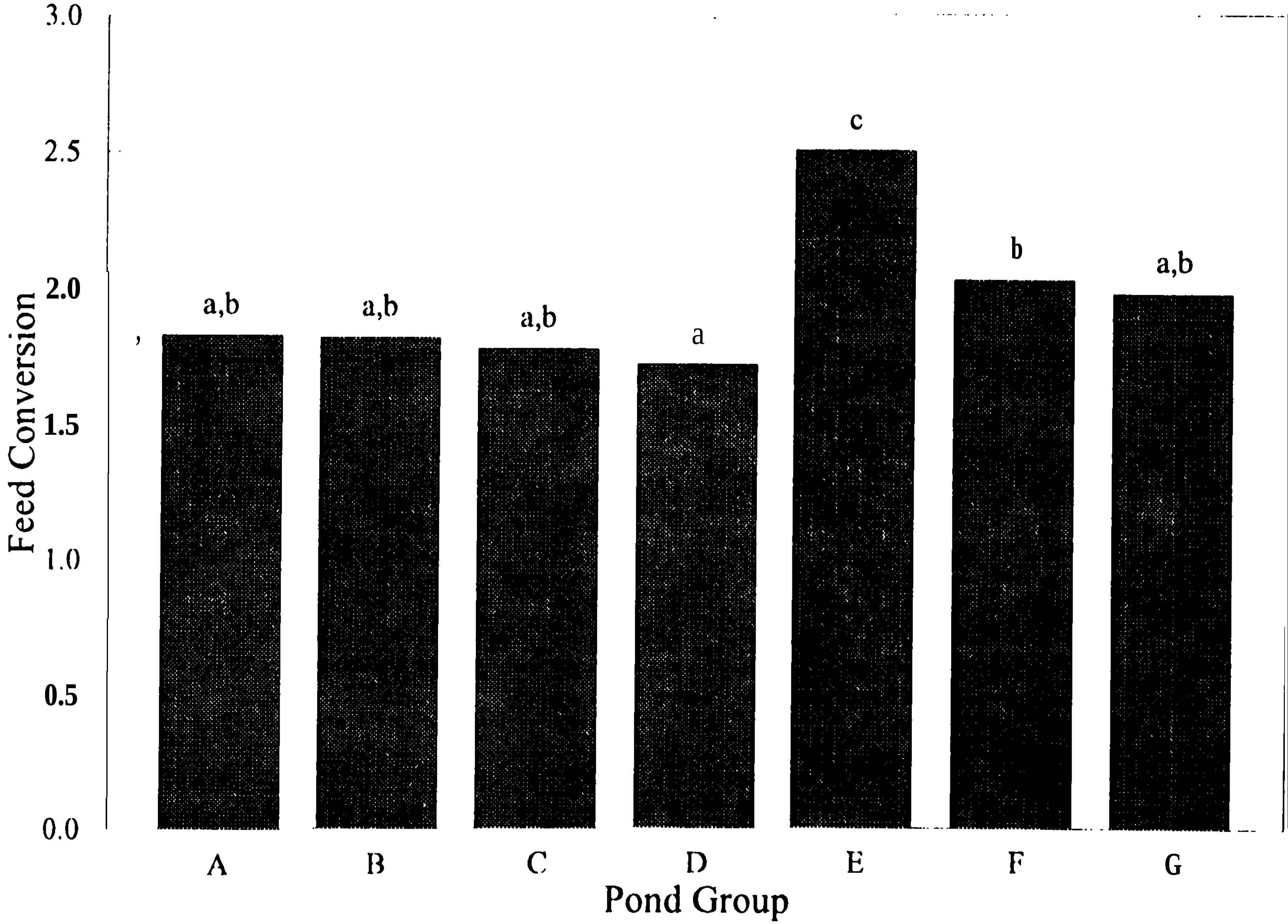
Length Frequencies

Length frequencies for all experimental fish were obtained in July during tagging, September, December and February. Skewness of length frequencies as a measure of symmetry about the mean did not show significant differences ($P \leq .05$) between groups (Table 27). No apparent pattern could be seen in the length frequency as a result of rearing density or treatment groups

Bcale Analyses

In both February 1993 and 1994, scale samples were taken from juvenile chinook in experimental ponds just before release. Scale radii were determined from these samples and plotted against fork length of the fish. Significant linear

Fig. 20. Average food conversions for spring chinook salmon reared in experimental ponds at Willamette Hatchery, 1990-1994. Bars with the same superscript are not significantly different.



3.0
2.5
2.0
1.5
1.0
0.5
0.0
Feed Conversion
a,b
a,b
a,b
a
c
b
a,b
A
B
C
D
E
F
G
Pond Group

Table 27. Skewness values from length frequency data for spring chinook salmon in various experimental raceways at Yillamette Hatchery, 1993-1994. Positive values indicate the population skewed to the smaller sizes and negative values indicate the population is skewed to the larger sizes.

Group	Jul	Sep	Dec	Feb
Al	-0.415	0.112	0.633	0.472
A2	0.044	-0.098	0.327	0.332
Bl	0.073	-0.028	0.155	0.446
B2	0.604	0.029	-0.033	-0.065
Cl	0.024	0.052	0.677	0.555
C2	0.394	0.331	0.288	0.652
Dl	-0.088	-0.436	0.466	0.374
D2	-0.387	0.902	0.347	0.069
El	0.090	0.665	0.596	-0.267
E2	-0.204	0.677	0.738	0.839
Fl	0.099	0.535	0.239	0.672
F2	-0.443	0.623	0.771	0.548
Gl	-0.238	0.420	0.914	0.497
G2	0.140	0.627	0.844	0.250

relationships were observed in both cases (Figs. 21 and 22). In 1993, the regression equation was 0.5078 (scale radius) + 6.984 (R^2 = 0.620). In 1994, the regression equation was 0.7017 (scale radius) + 3.060 (R^2 = 0.790). As adults return to the collection facility at Dexter, scales will be taken and the freshwater portion of the scale measured. From the regressions above, we hope to be able to estimate the size at which the juveniles entered the ocean. These data should confirm the size-at-release experiments of Smith et al. (1985) that indicate the appropriate sizes for survival in the ocean.

Fig. 21. Relationship between fork length (cm) and scale radius for juvenile spring chinook salmon reared in experimental raceways at Willamette Hatchery, 1992-1993. Radii were measured in mm from a 24X magnification of the scales.

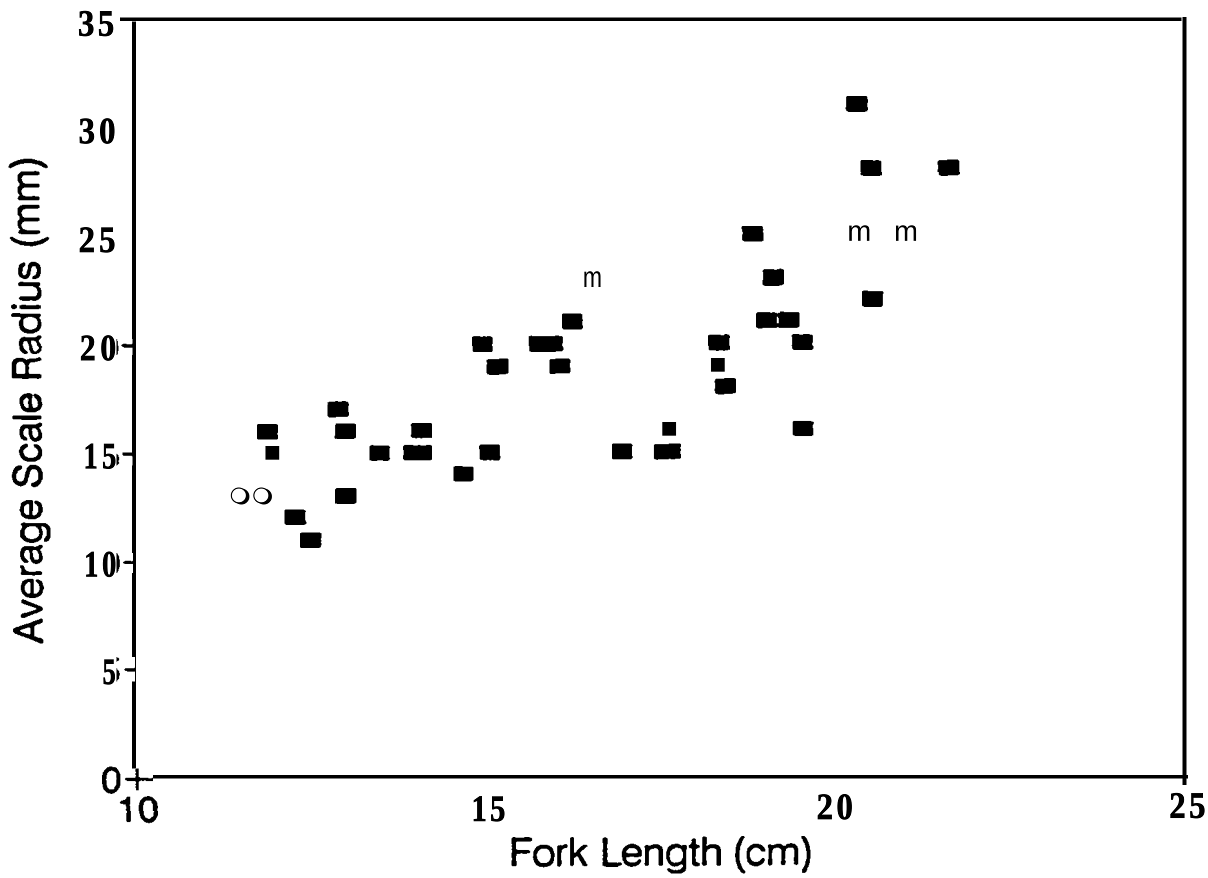
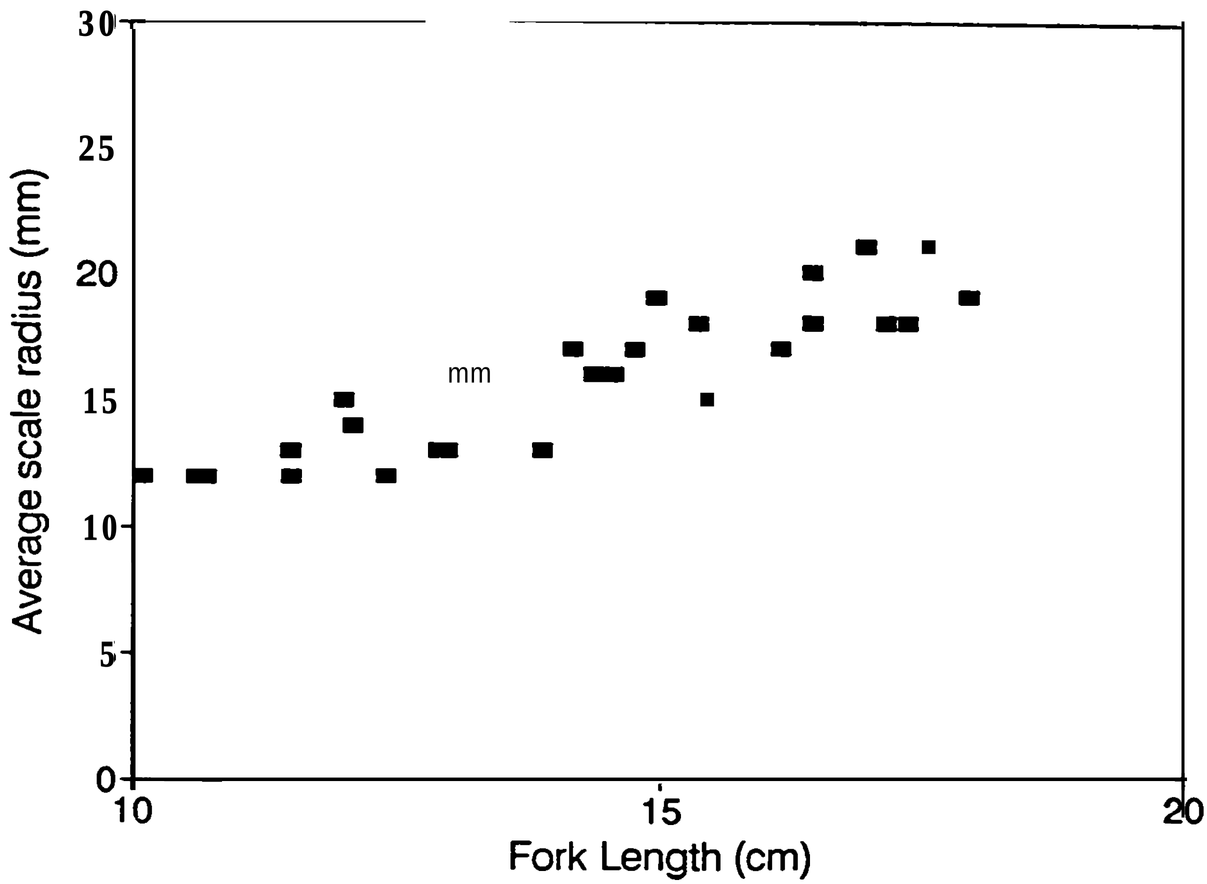

Average Scale Radius (mm)
35
30
25
20
15
10
5
0
10
15
20
25
Fork Length (cm)
m
m m

Fig. 22. Relationship between fork length (cm) and scale radius for juvenile spring chinook salmon reared in experimental raceways at Willamette Hatchery, 1993-1994. Radii were measured in mm from a 24X magnification of the scales.



Average scale radius (mm)
30
25
20
15
10
5
0
mm
10
15
20
Fork Length (cm)

Smolt Quality Assessment

Introduction

In the Columbia River Fish and Wildlife Program (1987), the Northwest Power Planning Council emphasized the importance of improving the effectiveness of hatcheries through the release of better-quality smolts. Section 703(e)5 calls for development of "a sensitive, reliable index for predicting smolt quality and readiness to migrate. The index shall be validated by conducting a test using a selected species and selected hatcheries." The Hatchery Effectiveness Technical Work Group suggested an activity 4.1.1: "Select and monitor through the rearing cycle, fish quality indices at four or more spring chinook hatcheries, and correlate these with performance indicators including survival through the adult state."

A study was funded from 1989 to 1992 by the Bonneville Power Administration to address these concerns. The study, Smolt Quality Assessment of Spring Chinook Salmon, Project No. 89-046, sampled fish from five hatcheries in the Columbia River basin to determine smolt characteristics. One of these hatcheries was Willamette Hatchery. The sampling design at Willamette Hatchery, however, did not address some of the more interesting issues concerning the effect of oxygen supplementation on smolting. During the first year of the study, no fish from the oxygen supplementation study were available. During the next two years, budget constraints permitted sampling of only two of the seven experimental groups in the Oxygen Supplementation Project.

In 1992-1993, we began sampling of all seven experimental groups of chinook salmon in the study for hematocrits, condition factor, liver glycogen and triglycerides, gill (Na+K)-ATPase activity, and plasma thyroxine, cortisol and glucose. Sampling was continued during the 1993-1994 rearing period. This sampling extended the data base from the previous Smolt Quality Assessment project to provide a continuous four-year record of smolting in some of the experimental groups at Willamette Hatchery. It also provided a comparison of smolting in fish reared under the seven experimental conditions described in Table 48. Data will also be used to correlate migration rate and survival to adulthood with the degree of smolting exhibited at Willamette Hatchery as this data becomes available.

This report describes the results from the second year of sampling for smolt quality parameters in fish from all experimental groups at Willamette Hatchery.

Haterials and Methods

Groups of 15 fish were sampled from the lower half of each of seven experimental raceways using a long-handled dipnet. Experimental groups are described in Table 2. Dipnet sampling was examined by the Smolt Quality Assessment study (1989) and found to provide representative samples from raceways. To minimize stress, groups of 10 or less fish were netted and sampled at any one time. The fish were transferred immediately to a bucket containing 200 mg/L MS-222 and 1 ml 5M imidazole/L and killed with an overdose of anesthetic to prevent changes in physiological parameters due to stress.

Fish were measured, weighed, and visually judged to be parrs, smolts or partly smolted. Parrs were defined as fish in which the parr marks were strongly developed, while smolts were defined as those in which the parr marks were barely visible. Partly smolted fish had silvery color which partly obscured the parr marks. Condition factor was calculated by the formula: KFL = weight (g)/length $(cm)^3$.

The caudal peduncle was severed and approximately 0.2 ml of blood was removed to a microcentrifuge tube and placed on ice. A heparinized microhematocrit tube was also filled with blood for hematocrit analysis. The liver was then removed and placed in a glass tube on dry ice. Gill filaments were excised and homogenized in a medium composed of 0.2 M sucrose, 0.01 M sodium EDTA, 0.01 M 2-mercaptoethanol, and 0.1 M imidazole, pH 7.2. The homogenate was transferred to a glass tube on dry ice for transport. Skin samples were taken by placing the fish on dry ice for several minutes until frozen. A circle of skin was removed with a cork borer from the midline just below the dorsal fin and placed in a glass tube on dry ice.

Small blood samples were centrifuged for 5 minutes in hematocrit centrifuge and read to the nearest 0.5 percent with a hematocrit reader. Hematocrit tubes were then frozen on dry ice for hemoglobin analysis. Large blood samples were centrifuged for

2 minutes at 1000 x g at room temperature, the plasma was removed with a Pasteur pipette, and the plasma was stored on dry ice in 0.5 ml microcentrifuge tubes.

After transport to the laboratory, livers were homogenized in 2.0 ml water. Two aliquots of 0.05 ml were removed for protein analyses, and aliquots of 0.2 ml were removed for triglyceride analyses. Glycogen was precipitated from the remainder with 5 volumes of ethanol according to the method of Montgomery (1957). Glycogen was measured by the colorimetric method of Dubois et al (1956). Triglyceride samples were diluted to 1.0 ml with water and heated at 75°C for 15 minutes. The samples were then cooled and centrifuged at 6000 rpm for 10 minutes in a Mistral 2000 refrigerated centrifuge. Supernatants were decanted for triglyceride analyses by the method of Bucolo and David (1973).

Gill ATPase activity was measured in gill homogenates by the method of Johnson et al. (1977). Protein was determined by a modification of the method of Lowry et al. (1951). Hemoglobin content of blood was measured from blood samples used for hematocrits. Volumes were determined by measurement of the length of the blood sample in mm and converting the length to volume by a standardized regression between known volumes of water and the length of the tube occupied by water. Hemoglobin was determined as the cyanomethemoglobin by the method of Rice (1967).

A new technique was used for determination of skin guanine. Staley and Ewing (1992) described guanine content in terms of ug guanine per mg of skin. This technique has difficulties associated with obtaining a reproducible sample without underlying muscle tissue and with extraction efficiency dependent upon sample size. To alleviate these difficulties, we used a cork borer to obtain a portion of skin of known area. Guanine concentrations were then related to this known area of skin. The area of the sample was obtained by weighing known areas from lined graph paper. A relationship between sample area and weight was established. Samples were then punched from the graph paper with a cork borer and weighed. The area indicated was 0.8874 cm^2. All measurements of guanine were subsequently expressed as ug guanine per cm^2 skin. In September, samples obtained with the cork borer from fish from groups E and F were also weighed. An average weight of 8.83 ± 0.39 (N=28) was obtained. From this value and the assumption that the weight per area remains constant throughout smolting, it is possible to relate previous values based on grams of skin to those based on cm^2 of skin by multiplying by 0.1005. Skin samples were extracted for 48 hours in 1 N HCl and assayed for guanine by the enzymatic method of Staley and Ewing (1992).

Plasma glucose was measured by a glucose oxidase method developed by Biotech Research and Consulting, Inc., for microliter quantities of plasma.

Comparisons between parameters of experimental groups and times were examined by 2-way analysis of variance (ANOVA). When significant differences were observed, individuals were compared by Tukey's test. Growth rates derived from dipnet samples were compared with those derived from monthly pond counts by chi square analysis. All analyses were performed at the 95% confidence level.

Results and Discussion

Sampling Procedures

A potential problem with dipnet sampling was whether the sample of 15 fish collected for smolt samples was representative of the population. During sampling in 1992-1993, it was found that dip-net samples from some raceways were significantly smaller than samples obtained by crowding the fish and taking dip-net samples of the crowded fish.

To examine this further in 1993-1994, weights of the 15 fish from each time point in the smolt sampling program were compared with those obtained by crowding the population and determining weights by pond counts (see Appendices on disks). Chi squared analysis indicated that the weight of the fish in the smolt samples was not significantly different from that of the pond counts (x^2 = 41.2; x^2(0.95, 47 d.f.) = 59.8). These results suggest that the dip net samples were representative of the population in the ponds. If weights for smolt samples and pond counts were combined for 1992-1993 and 1993-1994, weights of smolt samples were not significantly different from those of the pond counts (x^2 = 126.9; x^2 (0.95, 103 df) = 133.0).

Growth rates of the fish in the smolt samples were calculated by changes in fork length and weight and compared to those obtained from pond samples at the hatchery (Table 28). Most growth rates based on changes in fork length were similar except in group E. This slower apparent growth rate could also be seen with growth rates based on changes in weight. Growth rates based on changes in weight were similar for smolt samples and for pond counts except in Groups D, F, and G. In these groups, larger fish tended to be captured in the smolt samples.

Smolt Indices

Visual assessment of smolting indicated a size relationship to the coloration of the fish. Smaller fish tended to have less silvering, while larger fish had deciduous scales associated with smolting in chinook and parr marks that were obscured by silvering. Partially smolted individuals were intermediate in size (Fig. 23). The average length for fish in each of the smolt categories increased slightly with time (Fig. 24).

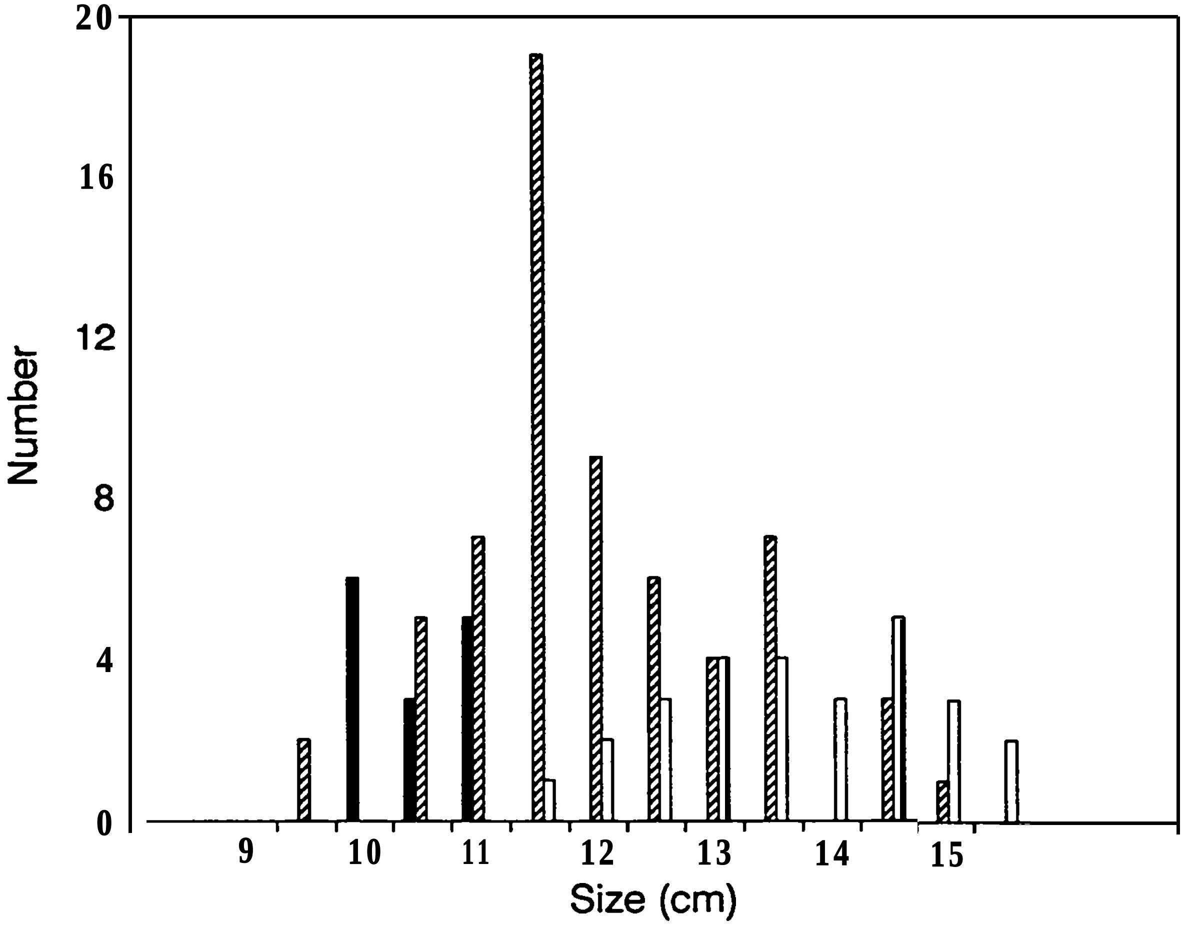
The percent of the sample consisting of parrs decreased continuously during the sampling year (Table 29), as would be expected if the smolt status was a function of size. However, these data were from pooled samples from all the raceways. There was a tendency for fish in the Michigan ponds to be somewhat more silvery than those in raceways in 1992-1993. However, in 1993-1994, there was no significant difference in guanine content per cm^2 between fish in raceways and those in Michigan ponds (Fig.

Table 28. Growth rates from smolt samples calculated as change in fork length (cm) per day and the change in weight (g) per day. Growth rates were obtained by linear regression analysis.

Group	Growth Rate (cm/day)	R2	Growth Rate (g/day)	R2	Growth Rate[1] (g/day)	R2
A	0.0207	0.659	0.097	0.577	0.096	0.694
B	0.0264	0.859	0.131	0.832	0.119	0.806
C	0.0203	0.774	0.091	0.743	0.110	0.827
D	0.0278	0.896	0.146	0.891	0.093	0.714
E	0.0176	0.752	0.075	0.655	0.086	0.829
F	0.0262	0.843	0.126	0.835	0.082	0.727
G	0.0249	0.888	0.114	0.847	0.078	0.723

[1]Growth rate calculated from pond inventories shown in Appendices on disks.

Fig. 23. Length frequencies of fish in the three smolting categories. Values are for fish from 105 samples taken in October 1993. Parrs, solid bars; partial smolts, heavy stripes: smolts, open bars.



20
16
12
8
4
0
Number
9
10
11
12
13
14
15
Size (cm)

Fig. 24. Average fork length (cm) for fish in parr (-■-), partially smolted (-□-), or smolted (-A-) condition with time of sampling.

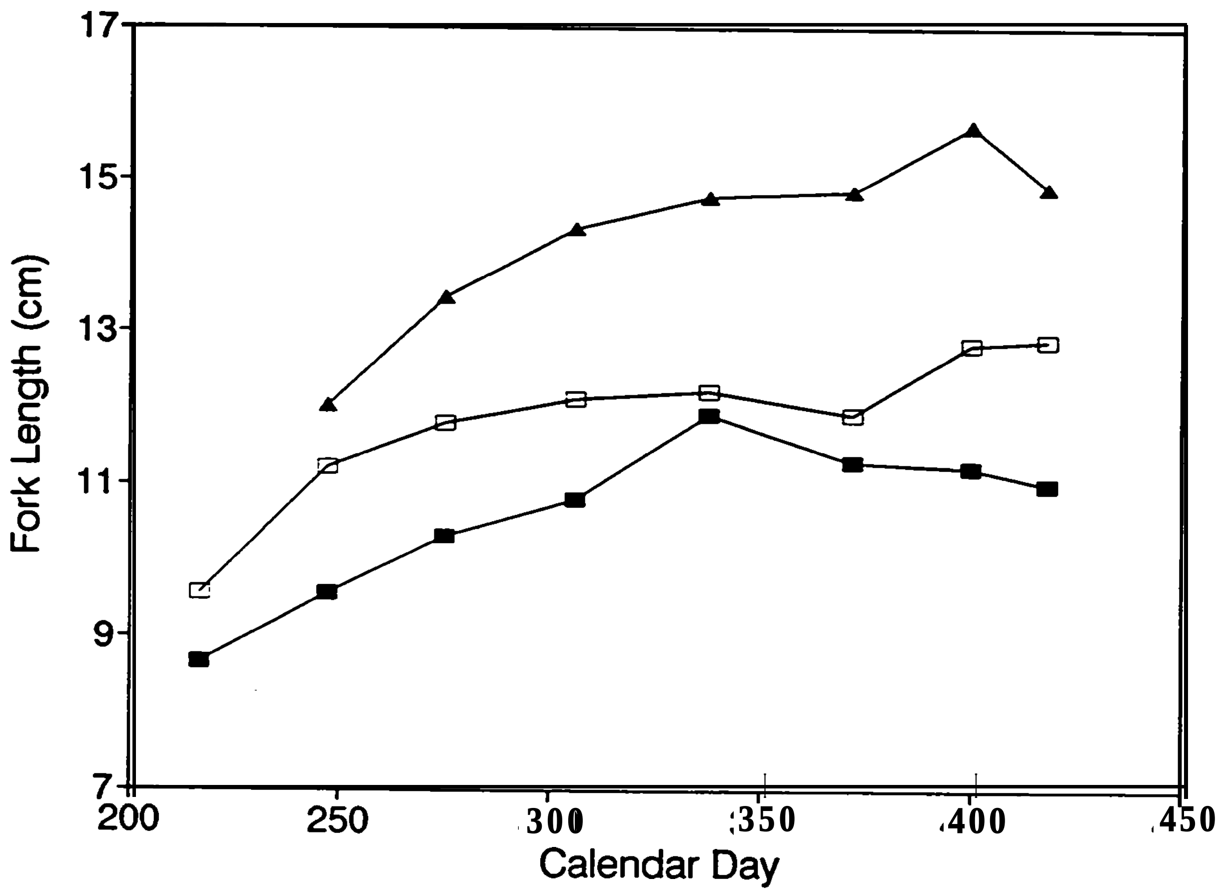

Fork Length (cm)
17
15
13
11
9
7
200
250
300
350
400
450
Calendar Day

Table 29. Percents of samples dipnetted from all raceways that were visually assessed to be parrs, partially smolted, or smolts.

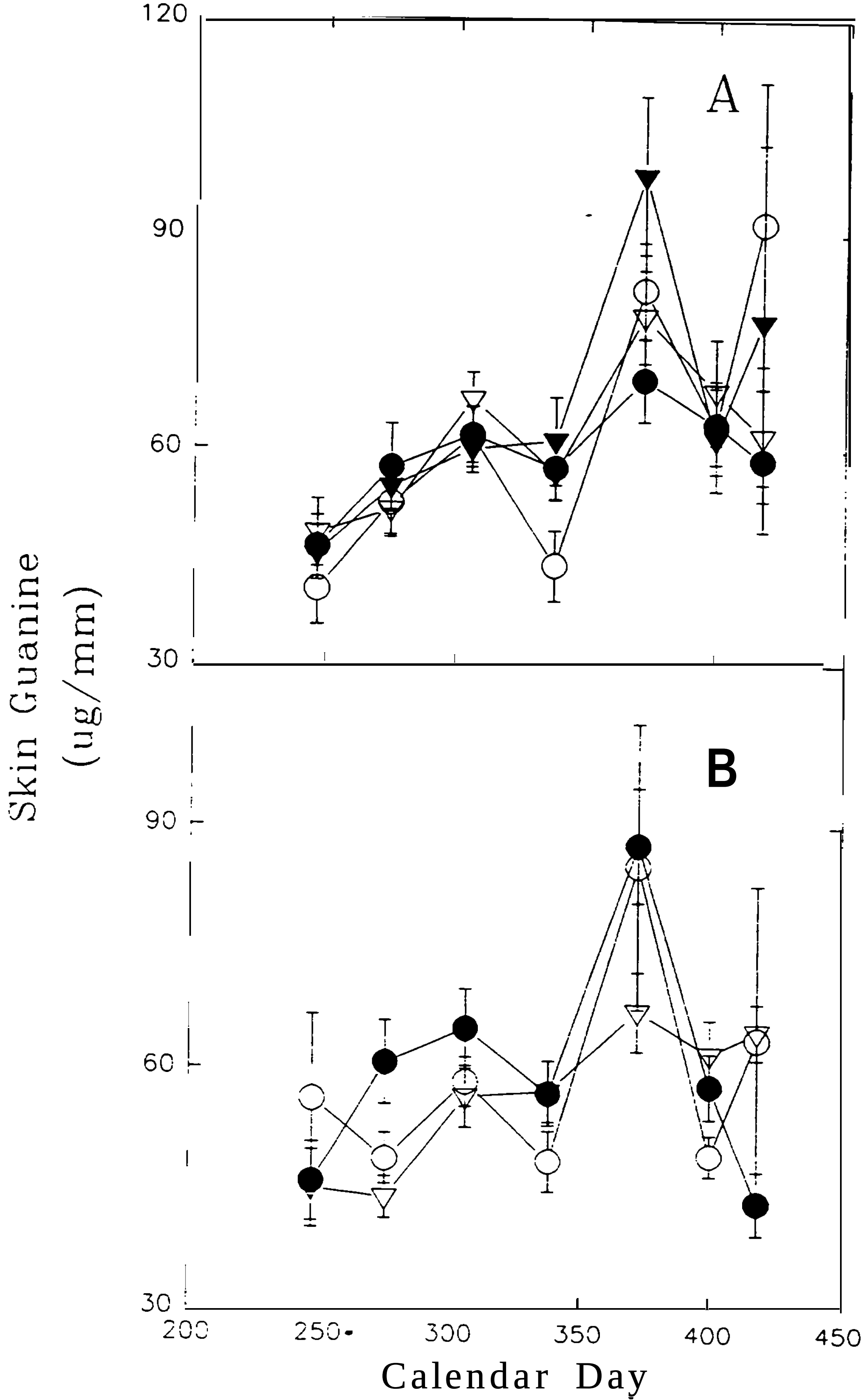
Date	Parr	Partial	Smolt
August	82.7	17.3	0.0
September	47.2	49.1	3.8
October	13.5	60.6	26.0
November	8.6	50.5	41.0
December	2.9	52.4	44.8
January	4.7	58.9	36.4
February	2.8	48.1	49.1
February 22	0.7	54.7	44.6

25). As expected from the smolt status, the guanine content of all groups tended to increase during the rearing cycle. However, there was a tendency to reach a maximum in January. This tendency was especially pronounced in groups E and F of the Michigan ponds.

The relationship between size and coloration had been suggested earlier for chinook salmon (Ewing and Birks, 1982). They suggested that chinook salmon reared in tanks lost their parr marks at 7 cm and remained silvery throughout the rest of their life until they entered freshwater as adults. The present results suggest that the size required for silvery coloration and loss of parr marks in raceways was at least 15 cm. Most of the fish tended to be in the partially smolted category, where the parr marks were still visible through an overlying layer of guanine.

The increase in silvering observed in the Michigan ponds in 1993 is intriguing and unexplained. Bouck (1972) reported that rock bass subjected to periods of hypoxia lost their olive green color and appeared more silvery. When normal levels of oxygen returned, the fish regained their normal color. The differences in coloration in the Michigan raceways should not be a result of hypoxia, because the oxygen concentrations in these raceways are no different than those seen in other raceways (Table 3). However, since the results could not be repeated in a more extensive examination throughout the sampling season, the results from 1993 may remain an unexplainable anomaly.

Fig. 25. Guanine content (μg/cm^2) in the skin of juveniles chinook salmon from various experimental groups. A. -●-, group A; -○-, group B; -▼-, group C; -∇-, group D. B. -●-, group E; -0-, group F; -▼-, group G;


A
B
120
90
60
30
90
60
30
Skin Guanine
(ug/mm)
200
250
300
350
400
450
Calendar Day

Condition factor was calculated monthly from length and weights of smolt samples (Fig. 26). Maximum levels occurred in September for fish in group D, E, and G, in October for groups A, C, and F, and in November for group B. During the peak, however, values on successive months are rarely significantly different, suggesting that all groups may be reaching a maximum in the general area of October. Values then dropped to reach a minimum in January and February. During the last samples on February 22, condition factor was again increasing. There seemed to be little difference in the patterns of change in condition factor between groups.

In 1993-1994, sampling for condition factor started a month earlier in August from that in 1992-1993. Consequently, a peak in condition factor was observed rather than decreasing values in the fall. Condition factor seemed to have reached a maximum earlier in 1992-1993, probably due to the warmer water temperatures and increased growth rates during that year.

Gill (Na+K)-ATPase activity showed fall peaks in activity in groups C, D, E and F (Fig. 27B and 27C). Groups A and B had no change from August to October, then dropped in specific activity in November. Specific activities for groups B, E, F, and G reached a minimum in December, then rose in the spring. Groups A, C, and D showed minimum specific activity in February. Activities rose slightly during the last sample point in late February. Analysis of variance indicated significant differences in activity throughout the year.

Fig. 26. Changes in condition factors with time for spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. -●-, group A; -0-, group B; -▼-, group C; -V-, group D. B. -●-, group E; -0-, group F; -▼-, group G;

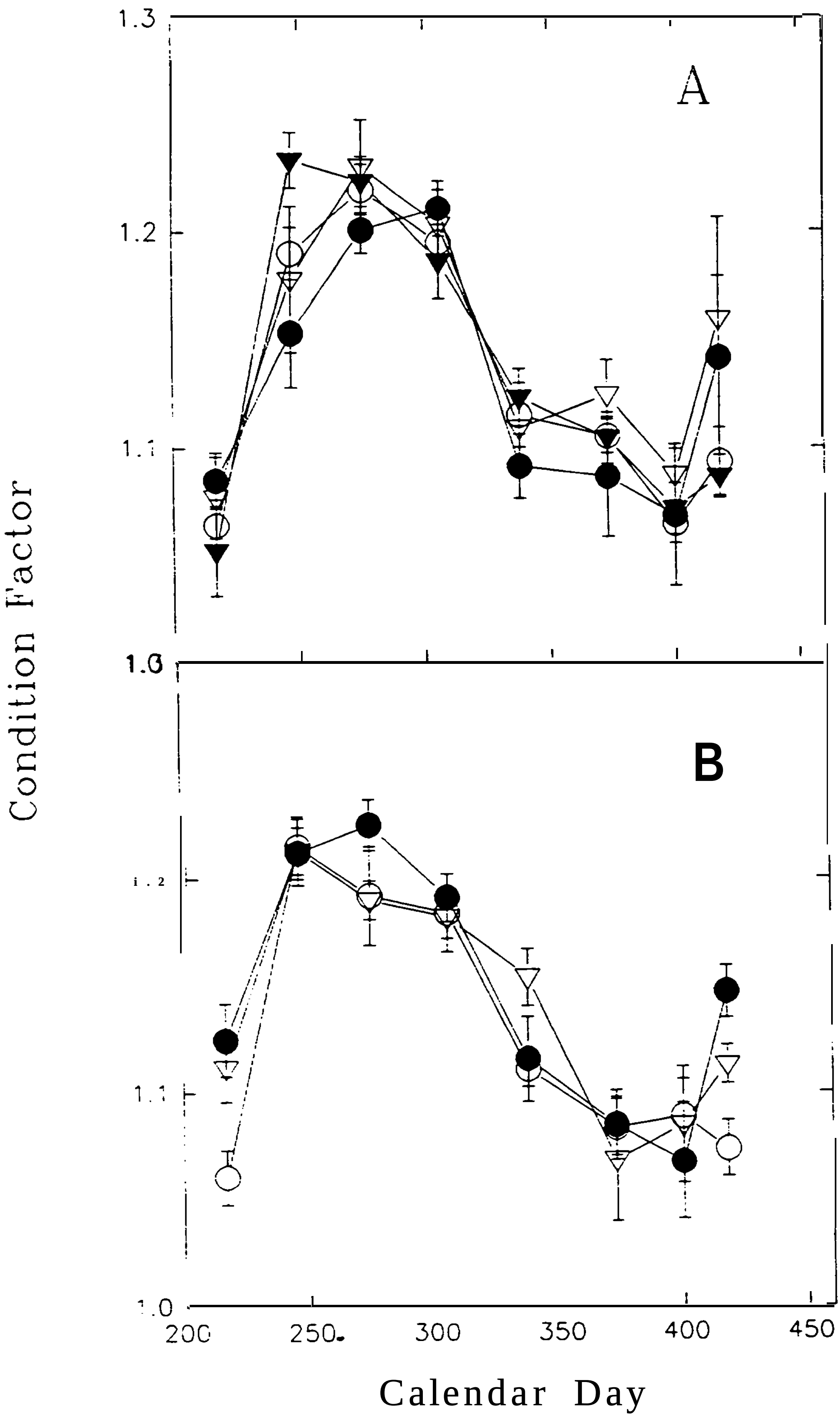
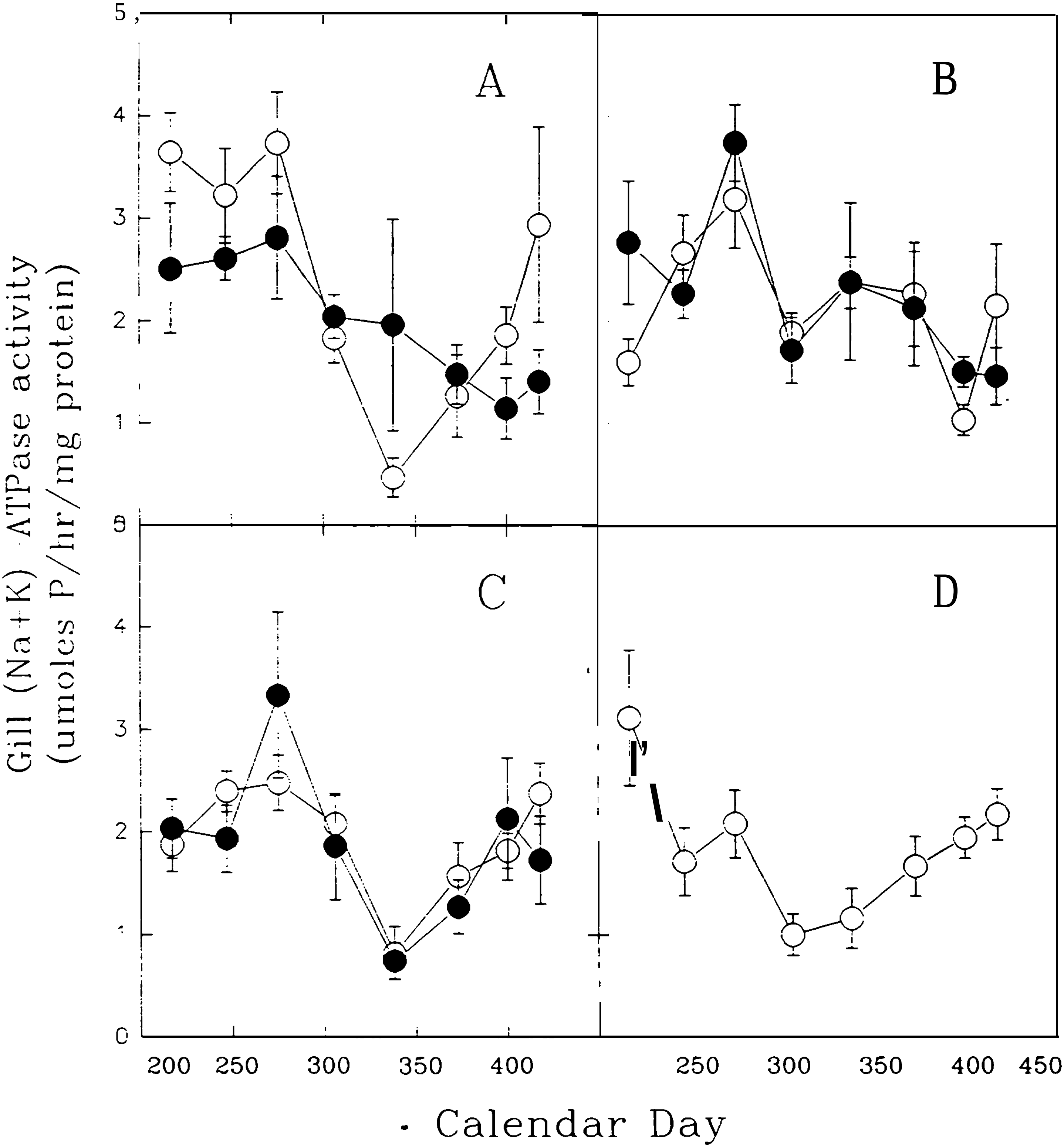

A
B
Condition Factor
1.3
1.2
1.1
1.0
200
250
300
350
400
450
Calendar Day

Fig. 27. Changes in gill (Na+K)-ATPase specific activity with time for spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. Group A, -●-; group B, -0-. B. Group C, -●-; group D, -0-. C. Group E, -●-; group F, -0-. Group G, -0-.



A
B
C
D
Gill (Na+K) ATPase activity
(umoles P/hr/mg protein)
0
1
2
3
4
5
200
250
300
350
400
450
Calendar Day

In contrast to last year, groups E and F of the Michigan ponds showed good patterns of changes in activity during the year (Fig. 27C), although the average specific activity was lower than that of the other ponds. Specific activity of group G showed only a decrease in activity from August to December, then a general rise in activity until February and release of the fish. Analysis of variance indicated significant differences in activity in all groups during the year.

Liver glycogen in groups B, C, D, E and G showed a peak in concentration in November (Fig. 28). Liver glycogen in groups A and F did not change significantly during the fall. All groups reached a minimum level near the first of February and an increase in concentration at the last of February. Glycogen levels seemed to reach a maximum a month after condition factors reached a maximum in most ponds. The significance of this is not clear, although it may represent a trend toward equilibrium with the stored fats that cause the changes in condition factor.

Liver triglycerides tended to reach a peak in concentration in November in all groups except groups A and E (Fig. 29). A peak in triglyceride concentration was reached in February in groups E and G and then decreased just before release. This pattern was similar to that seen last year. However, in groups A, B, C, D, and F, there was little change in triglyceride concentrations between January and March. Even in these, there was a tendency for triglycerides to drop just before release.

The suggested increase in energy metabolism indicated by the capture of smaller fish in group C is not supported by the

Fig. 28 Changes in liver glycogen (µg/mg protein) with time in spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. **A. Standard raceways: group A,-●- , group B, -0 -; group C, -▼-; group D,** -V-. **B. Michigan pond: group E -●-; group F -0-; group G** -V-.

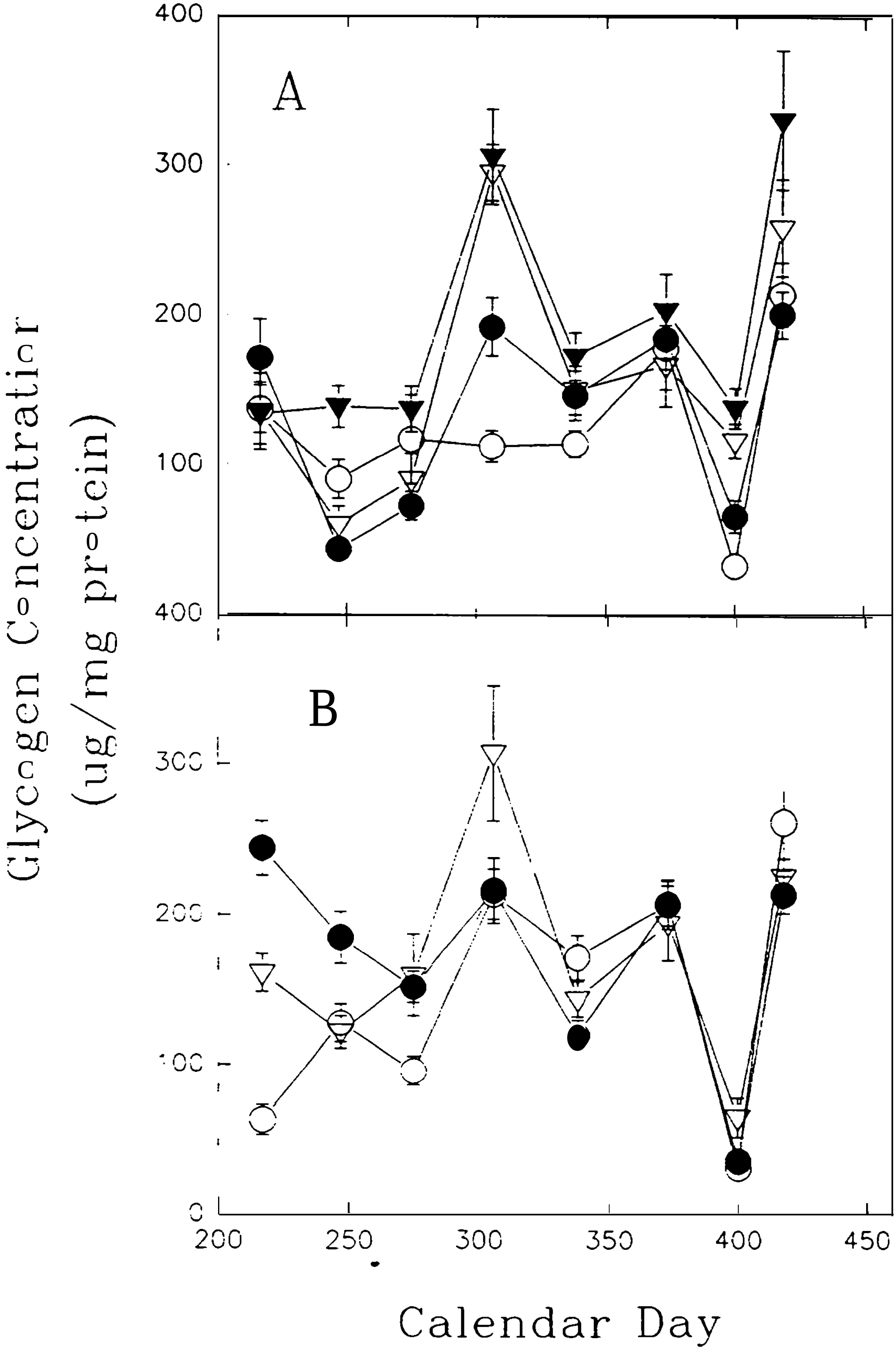
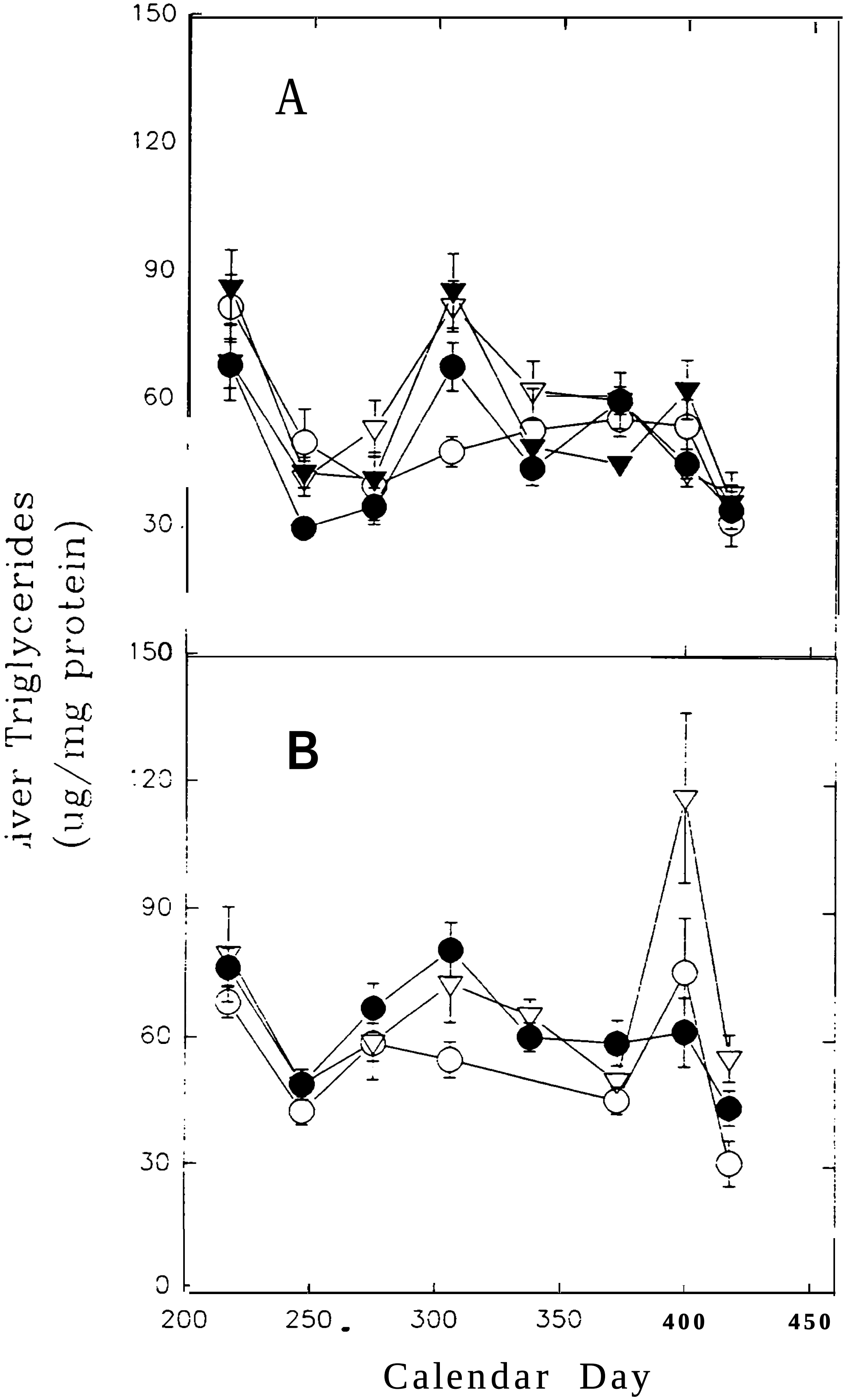

A
B
400
300
200
100
400
300
200
100
0
200
250
300
350
400
450
Glycogen Concentration
(ug/mg protein)
Calendar Day

Fig. 29. Changes in liver triglycerides (µg/mg protein) with time in spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. Standard raceways: group A, -@- , group B, -0-; group C, -▼-; group D, -V-. B. Michigan pond: group E -●-; group F -0-; group G -V-.


A
B
150
120
90
60
30
0
200
250
300
350
400
450
iver Triglycerides
(ug/mg protein)
Calendar Day

measurements of compounds used to provide energy for the fish, glycogen and triglycerides. No differences in levels of glycogen or triglycerides were observed between group A without oxygen and group C with added oxygen. These are relatively crude measurements of energy reserves, however. Greater refinements of energy utilization in the fish of the two different groups, such as energy charge, creatine phosphate concentrations, or mitochondrial function, may be required before these differences can be distinguished.

Blood hematocrits showed a general increase during the year (Fig. 30) in all groups except group A, which showed a maximum hematocrit in September. Groups F and G showed no significant differences throughout the sampling season.

Blood hemoglobin levels changed little during the winter, but began to increase just before release (Fig. 31). No significant differences were observed between raceways provided with supplemental oxygen and those without supplemental oxygen. Under the conditions of rearing at Willamette Hatchery, the presence of maximum levels of oxygen do not seem to influence the amount of hemoglobin in the blood.

Plasma glucose levels gradually decreased to a minimum in winter then tended to increase in January or February in most groups (Fig. 32). Lowest values were obtained during the last sample point. The pattern was approximately the same in all raceways. Maximum levels attained were about 70 mg/dL, which seems more reasonable than the high values of 150-200 mg/dL obtained last year.

Fig. 30. Changes in blood hematocrit with time in spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. Group A, -●-; group B, -0-. B. Group C, -●-; group D, -0-. C. Group E, -●-; group F, -0-. D. Group G -0-.

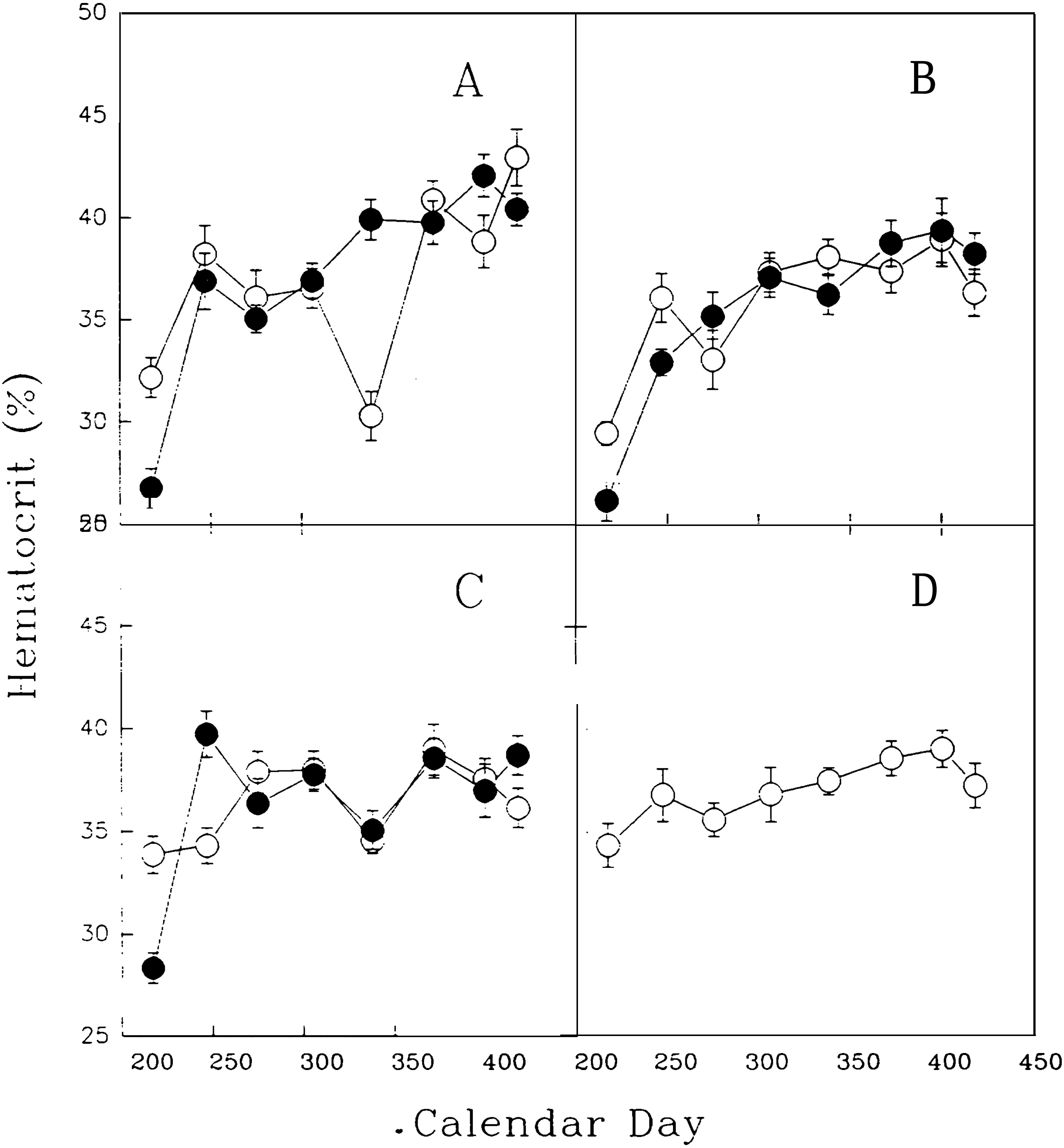

A
B
C
D
Hematocrit (%)
Calendar Day
50
45
40
35
30
25
200
250
300
350
400
450

Fig. 31. Changes in blood hemoglobin content(g/dL) with time for spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. Group A, -●-; group B, -0-; group C, -▼-; group D, -V-. B. Group E -●-; group F -0-; group G -∇-.

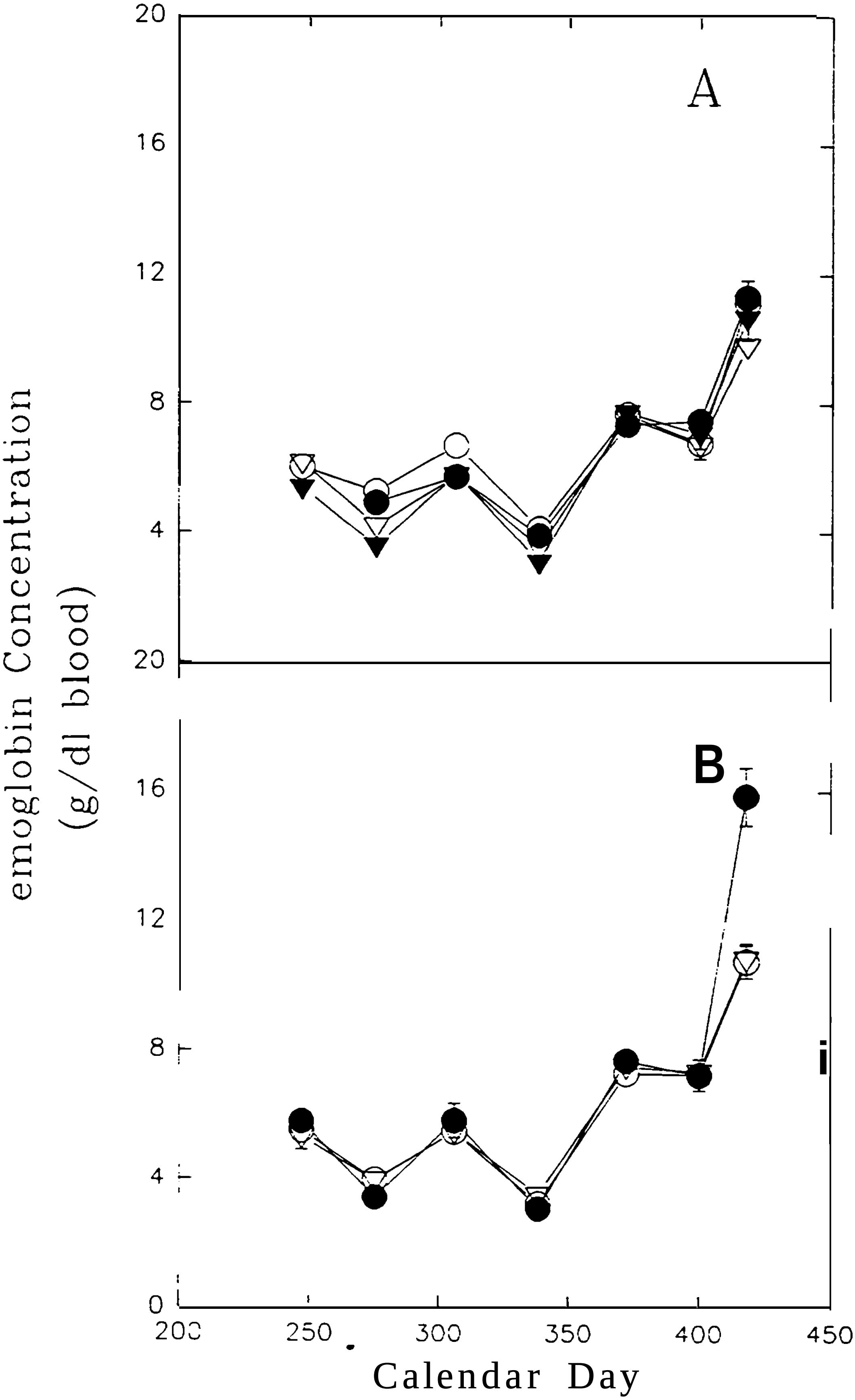
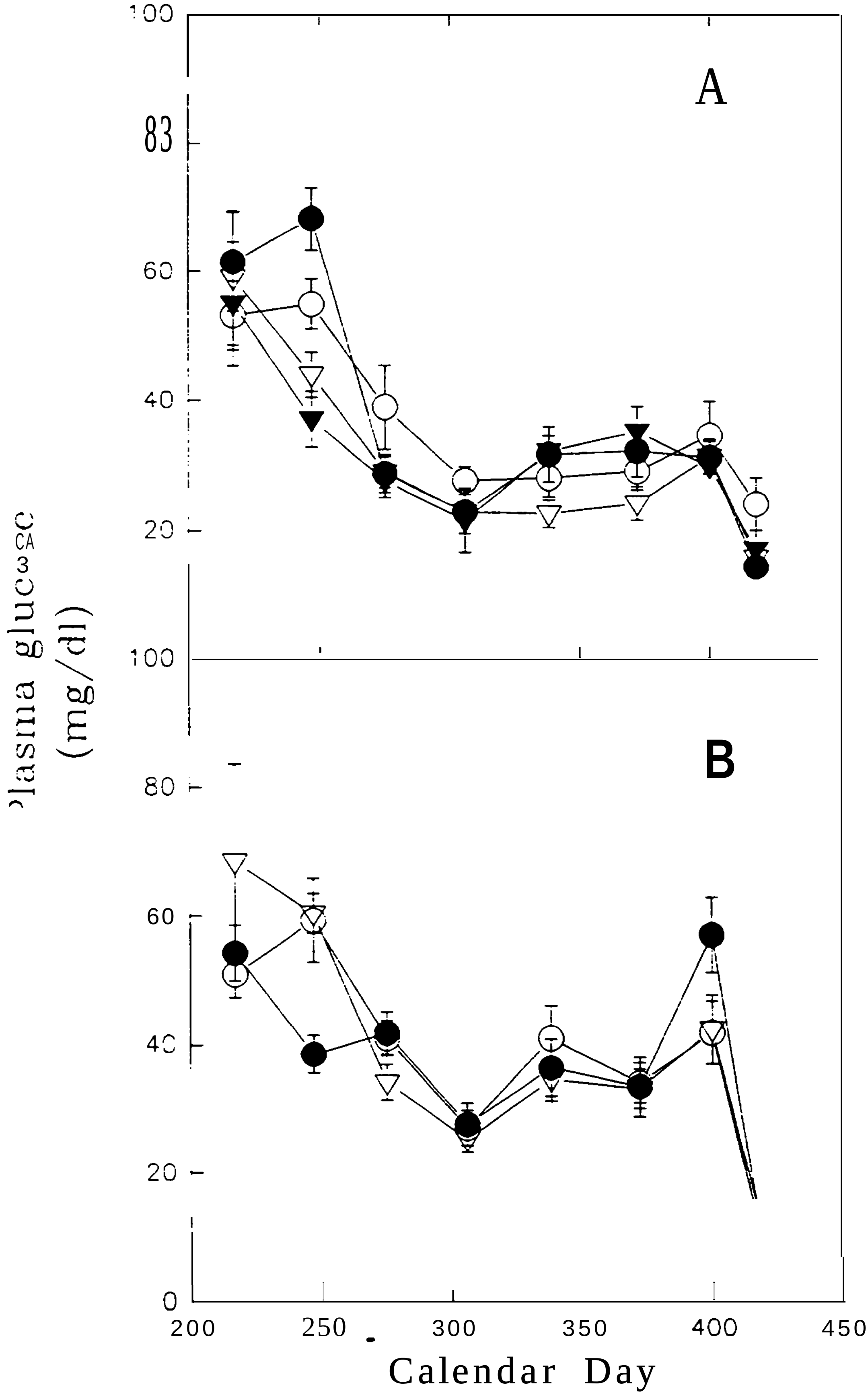

A
B
emoglobin Concentration
(g/dl blood)
20
16
12
8
4
20
16
12
8
4
0
200
250
300
350
400
450
Calendar Day

Fig. 32. Changes in plasma glucose concentrations (mg/dL) with time for spring chinook salmon reared in seven experimental raceways at Willamette Hatchery, 1993-1994. A. Group A, -●-; group B, -0-; group C, -▼-; group D, -V-. B. Group E -●-; group F -0-; group G -V-.



A
B
100
83
60
40
20
100
80
60
40
20
0
200
250
300
350
400
450
Calendar Day
Plasma glucose
(mg/dl)

Adult Recoveries

Information on coded wire tags collected from experimental spring chinook salmon released from Willamette Hatchery were compiled by the Pacific Fisheries Management Council (PFMC) computer data base and collected from returns to Willamette Hatchery. Preliminary analyses of the data are shown in Tables 30 and 31. The highest percent returns were from fish that were reared at Willamette Hatchery until November and then transferred to the Dexter holding pond (groups Dxl and Dx2). These fish were not part of the experimental design but were tagged for comparison with experimental fish. The number of fish reared each year varied: 147,859 for the 1989 brood, 382,000 for the 1990 brood, 382,024 for the 1991 brood and 308,727 for the 1992 brood.

The second highest percent returns were from fish reared at half the normal rearing density (group B, followed by fish reared at normal density with oxygen (group C). All other groups showed less that 0.3% return. The same pattern resulted from comparing the number of adults recovered per 1000 kg of fish released.

The inverse relationship between density and adult contribution was observed earlier at the Carson Hatchery where spring chinook smolt production levels of 20,000, 40,000, and 60,000 fish per raceway resulted in overall adult yields of 79, 78, and 70 fish per raceway respectively (Banks 1994).

Table 30. Preliminary analysis of adult contributation by tag code and group of spring chinook salmon released from Willamette Hatchery.

Tag Code	Brood year	Pond	Percent return	Group Mean	Adults per 1000 kg smolts	Group Mean	Cost $/adult	Group Mean
07-55-14	89	Al	0.19		45.75		13.28	
07-56-14	89	A2	0.14	0.16	30.94	38.35	24.61	17.77
07-55-17	89	B1	0.63		134.26		4.18	
07-55-18	89	B2	0.56	0.59	134.50	134.38	5.90	4.96
07-54-63	89	Cl	0.52		122.06		12.10	
07-55-03	89	C2	0.50	0.51	115.99	119.03	11.57	11.83
07-55-07	89	D1	0.22		73.53		17.73	
07-55-08	89	D2	0.29	0.26	78.73	76.13	15.67	16.66
07-55-09	89	El	0.02		5.47		318.61	
07-55-10	89	E2	0.06	0.04	19.80	12.63	74.34	121.83
07-55-11	89	F1	0.03		7.75		201.16	
07-55-12	89	F2	0.07	0.05	22.37	15.06	61.94	95.40
07-55-13	89	G1	0.02		5.02		334.59	
07-55-05	89	G2	0.01	0.01	3.40	4.21	477.27	392.61
07-55-16	89	Dxl	0.85		304.80		12.94	
07-55-15	89	Dx2	0.76	0.80	273.31	289.05	14.44	13.65

Table 31. Preliminary analysis of adult contributation by tag code and group for spring chinook salmon released from Willamette Hatchery.

Tag Code	Brood year	Pond	Adults/ 100M3	Group Mean	Adults/ 1000 L/min	Group Mean
07-55-14	89	Al	68.09		37.70	
07-56-14	89	A2	44.59	56.34	24.69	31.19
07-55-17	89	B1	117.41		65.01	
07-55-18	89	B2	96.87	107.14	53.64	59.32
07-54-63	89	Cl	185.30		102.60	
07-55-03	89	C2	184.30	184.80	102.04	102.32
07-55-07	89	D1	261.81		144.96	
07-55-08	89	D2	283.65	272.73	157.05	151.00
07-55-09	89	El	14.25		2.63	
07-55-10	89	E2	59.06	36.65	10.90	6.76
07-55-11	89	F1	24.74		4.57	
07-55-12	89	F2	78.21	51.47	14.43	9.50
07-55-13	89	G1	14.46		2.67	
07-55-05	89	G2	9.91	12.19	1.83	2.25
07-55-16	89	Dxl	41.30		13.43	
07-55-15	89	Dx2	37.03	39.16	12.04	12.74

The cost to produce an adult salmon under each of the experimental conditions was calculated from the returns and from the costs of rearing at Willamette Hatchery. Oxygen costs were determined by the total volume of oxygen used in the experimental pond plus the fixed cost of the tank rental and the fee charged by the State Fire Marshal for Hazardous material. The total cost of rearing was assumed to be the cost of fish feed from August 1 to release and the cost of oxygen if used. The estimate of total cost did not include personnel, tagging, or electrical costs for pumping 750 gpm of water to ponds F and G.

The lowest cost per adult was obtained from the fish reared at half the normal density (group B), while the highest costs per adult were obtained from the Michigan ponds. The small number of adults recovered for groups E, F, and G resulted in an extremely high cost subject to large error. For example, if 2 additional fish were captured in the ocean fishery and expanded for group G1, the cost per adult would decrease by $212.92.

Single pass triple density ponds (group D) produced more adults per 100 m^3 and adults per 1000 L/min than any other experimental group (Table 31). However, numbers were only 47.6 % greater than those from fish reared at normal density with oxygen (group C). The number expected would be 200% higher if oxygen was the only determining factor. The lower values for the Dexter fish are due to the dimension of the pond and the high water flow though the pond. These preliminary results suggest that if rearing space or flow can not be increased and adult contribution needs to be increased, addition of oxygen or rearing at higher densities will accomplish this task.

It should be emphasized that these data are preliminary and conclusions may change with the addition of more data.

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APPENDIX A

Dissolved Oxygen Concentration (ppm) at Inflow (I) and Outflow (0) of Experimental Raceways at Willamette Hatchery, 1993-1994.

Group	I/0	08/07/91	08/14/91	08/21/91	08/28/91	09/06/91
Al	I	10.05	9.83	8.05	9.38	8.88
	0	9.32	9.27	7.29	8.61	7.71
A2	I	9.91	9.21	9.15	9.80	9.41
	0	9.11	8.46	8.29	9.29	8.44
Bl	I	10.05	9.83	8.05	9.38	8.88
	0	9.59	9.51	7.52	8.86	8.31
B2	I	9.91	9.21	9.15	9.80	9.41
	0	9.44	8.76	8.81	9.51	8.62
Cl	I	10.46	11.99	9.78	11.41	10.79
	0	9.85	11.20	8.98	10.27	9.24
c2	I	10.00	10.58	10.79	11.90	11.44
	0	9.22	9.58	10.15	10.97	10.96
Dl	I	13.13	14.09	11.89	13.69	13.42
	0	10.83	12.37	9.04	11.11	8.76
D2	I	12.51	13.66	12.63	14.19	14.28
	0	10.24	10.72	11.12	11.04	11.92
El	I	11.19	11.24	11.26	12.07	11.36
	0	10.13	10.48	10.23	11.13	10.40
E2	I	11.10	10.69	9.95	11.45	11.27
	0	10.16	9.59	8.70	10.11	9.65
Fl	I	11.26	11.92	12.26	13.39	12.58
	0	10.07	10.48	10.54	11.49	10.48
F2	I	11.66	11.37	10.68	12.18	12.60
	0	10.16	9.67	8.94	10.35	10.57
Gl	I	11.58	12.26	13.34	14.86	14.04
	0	10.18	10.80	11.13	12.77	11.29
G2	I	11.74	11.24	11.11	13.16	12.94
	0	10.18	9.54	9.05	10.72	10.44

Appendix Table A (continued).

Group	I/0	9/25/91	10/16/91	10/25/91	1l/06/92	1l/13/91
Al	I	11.12	10.89	11.39	10.88	-
	O	10.08	9.87	10.03	9.43	9.37
A2	I	10.22	10.44			11.08
	O	9.48	8.67	-	-	9.78
Bl	I	11.12	10.87	11.39	10.88	10.00
	O	10.70	10.37	10.56	9.86	9.49
B2	I	10.12	10.44			11.08
	O	8.99	9.44	-	-	10.51
Cl	I	12.36	13.10	13.51	12.28	11.67
	0	11.81	11.11	12.00	10.95	11.00
c2	I	12.32	12.26	-	11.89	12.41
	0	10.99	10.56	-	11.09	11.89
Dl	I	16.71	16.09	14.94	15.33	13.17
	0	13.21	12.17	12.83	11.26	11.20
D2	I	13.48	13.87		15.73	16.29
	O	10.11	10.42	-	12.33	14.07
El	I	12.31	13.20	14.56	12.75	12.44
	0	11.32	12.11	13.66	11.14	11.34
E2	I	12.82	12.54	-	12.83	11.65
	O	11.32	11.17	-	11.67	10.24
Fl	I	14.30	15.19	15.47	13.47	13.39
	O	11.82	12.08	13.05	10.63	11.24
F2	I	14.53	12.84		13.78	13.52
	O	11.19	11.26	-	11.07	11.79
Gl	I	15.52	16.74	17.69	13.66	13.84
	0	13.21	13.35	14.68	10.95	12.04
G2	I	14.22	14.26		13.60	13.81
	O	11.79	11.10		11.14	12.25

Appendix Table A (continued).

Group	I/O	11/20/91	11/27/92	12/4/91	12/11/91	12/19/91
Al	I	10.59	11 .00	11.38	12.22	13.32
	O	10.14	10.49	10.79	11.34	12.18
A2	I	11.84	11.50	11.39	11.14	
	O	11.18	10.97	10.61	10.61	
Bl	I	10.59	11.00	11.38	12.22	13.32
	O	10.29	10.69	10.95	11.66	12.62
B2	I	11.84	11.50	11.39	11.14	
	O	11.73	11.12	10.79	10.61	
Cl	I	12.15	11.71	12.44	12.41	13.75
	O	11.41	11.56	11.83	12.01	13.52
c2	I	12.93	12.34	11.90	12.40	
	O	12.41	11.96	11.52	11.65	
Dl	I	13.73	13.04	13.33	13.17	14.15
	0	12.03	11.71	11.85	12.28	13.09
D2	I	15.96	14.24	13.75	13.88	
	O	13.45	13.10	12.05	12.80	
El	I	11.73	13.61	13.50	13.27	14.12
	0	11.06	12.69	12.33	12.70	12.73
E2	I	13.84	13.67	13.08	14.39	
	O	12.90	12.75	12.17	12.33	
Fl	I	13.12	14.61	13.78	14.54	14.08
	O	11.23	12.69	12.07	12.67	12.31
F2	I	14.92	14.43	13.58	13.83	
	0	13.09	11.84	12.04	11.87	
Gl	I	13.46	15.35	14.29	15.03	14.89
	0	11.93	13.35	12.32	13.09	12.96
G2	I	15.77	14.78	14.17	14.36	-
	O	13.60	12.77	12.51	12.51	-

Appendix Table A (continued).

Group	I/O	12/23/91	12/30/91	01/08/92	01/15/92	01/22/92
A1	I	12.38	12.30	13.23	13.93	13.13
	O	12.26	11.07	12.18	12.35	12.10
A2	I	12.99	13.14	12.80	13.43	13.27
	O	11.93	12.22	12.07	11.71	12.54
B1	I	12.22	12.30	13.23	13.93	13.11
	O	11.99	11.50	12.85	13.16	13.18
B2	I	12.99	13.14	12.80	13.43	13.27
	O	12.66	12.61	12.41	12.70	13.35
C1	I	13.60	13.04	13.60	14.02	14.71
	O	13.40	12.62	13.43	13.84	13.71
C2	I	13.70	13.84	14.56	14.76	15.10
	O	13.30	13.43	14.30	13.63	14.44
D1	I	14.00	13.78	15.11	16.82	14.13
	O	12.78	12.01	13.90	13.80	12.63
D2	I	14.76	14.75	15.36	15.52	15.88
	O	13.27	12.57	14.56	13.47	15.10
E1	I	13.77	13.98	14.31	15.43	14.62
	O	13.31	12.90	13.13	13.62	14.20
E2	I	14.39	14.38	14.64	14.99	15.71
	O	13.16	13.06	12.78	12.77	13.81
F1	I	13.81	14.43	15.07	16.08	17.34
	O	12.07	11.98	13.52	12.44	13.48
F2	I	15.01	14.35	14.76	16.12	16.99
	O	13.18	12.38	13.12	12.90	13.33
G1	I	14.68	14.96	15.24	16.53	16.96
	O	12.17	12.99	14.07	13.68	12.95
G2	I	15.71	14.40	16.21	16.32	18.21
	O	12.73	12.75	14.72	13.91	15.10

Appendix Table A (concluded).

Group	I/O	01/29/92	2/05/92	02/12/92	02/24/92
Al	I	12.15	12.50	11.63	11.65
	O	10.51	11.00	10.15	10.15
A2	I	11.83	12.35	10.97	11.42
	0	10.72	10.91	7.85	10.11
Bl	I	12.15	12.50	11.63	11.65
	0	11.19	11.50	10.85	10.69
B2	I	11.83	12.35	10.97	11.72
	O	11.03	11.64	9.92	11.02
Cl	I	13.33	14.71	12.94	12.92
	0	12.21	14.08	11.76	11.47
c2	I	13.98	13.71	12.61	12.61
	O	12.58	12.41	9.77	11.07
Dl	I	14.66	15.54	15.10	14.59
	0	11.40	13.80	11.74	12.01
D2	I	15.69	14.89	15.42	14.09
	O	13.13	12.88	12.26	12.31
El	I	14.71	15.20	14.34	13.54
	0	12.97	13.28	12.28	11.66
E2	I	14.71	14.29	13.62	13.53
	O	12.25	12.70	11.99	12.34
Fl	I	14.86	15.62	14.97	14.67
	O	11.87	13.06	11.33	12.10
F2	I	14.40	15.22	16.00	15.58
	O	11.57	12.21	12.60	12.09
Gl	I	15.80	17.53	16.67	15.77
	0	12.34	13.91	13.32	12.77
G2	I	14.83	16.12	17.08	16.42
	O	12.01	12.88	13.14	12.49

APPENDIX B

Dissolved gas pressures and temperatures of inflow (I) and outflow (0) from experimental raceways at Willamette Hatchery, 1993-1994

Group	I/O	Bar	Temp C	Pt	% SAT	PC2	Pt-pO2	Do ppm
08/11/93								
Al	I	735	12.6	743	101.6	153	590	14.11
Al	0	735	12.4	737	100.6	138	600	9.34
A2	I	734	15.1	743	101.7	151	593	9.69
A2	0	734	14.7	735	100.6	140	596	9.06
Bl	I	735	12.6	743	100.6	153	590	9.90
Bl	0	735	12.5	742	101.3	147	596	9.94
B2	I	734	15.1	743	101.7	151	593	9.69
B2	0	734	14.9	742	101.6	143	600	9.21
Cl	I	735	11.8	736	100.5	171	564	11.02
Cl	0	735	12.0	736	100.6	160	578	11.01
c2	I	734	14.2	719	98.5	181	541	11.83
c2	0	734	14.5	722	98.8	170	552	11.05
Dl	I	735	11.5	720	98.2	222	506	14.42
Dl	0	735	11.6	716	97.7	170	546	11.78
D2	I	734	13.9	699	95.6	228	473	15.00
D2	0	734	14.1	688	94.0	201	488	13.17
El	I	735	11.7	708	965.0	181	528	12.49
El	0	736	11.7	702	95.6	173	529	11.94
E2	I	735	12.8	718	98.1	180	538	12.12
E2	0	734	13.0	710	97.1	167	544	11.20
Fl	I	736	11.7	689	93.8	201	486	13.87
Fl	0	736	11.8	677	92.2	173	503	11.91
F2	I	734	13.2	706	96.4	180	527	12.02
F2	0	734	13.5	698	95.4	161	238	10.68
Gl	I	735	11.8	672	91.6	240	430	16.52
Gl	0	735	11.5	661	70.1	209	454	14.48
G2	I	735	13.7	687	93.9	217	472	14.34
G2	0	734	13.8	679	92.8	202	478	13.32

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
08/18/93								
Al	I	731	11.4	738	101.3	153	586	10.63
Al	0	732	11.3	732	100.4	143	591	9.95
A2	I	729	14.2	739	101.8	149	590	9.74
A2	0	729	13.8	731	100.6	135	598	8.90
Bl	I	731	11.4	738	101.3	153	586	10.63
Bl	0	731	11.4	736	101.0	148	588	10.28
B2	I	729	14.2	739	101.8	149	590	9.74
B2	0	729	14.0	738	101.7	143	596	9.39
Cl	I	731	11.0	732	100.5	167	567	11.70
Cl	0	732	11.1	734	100.6	161	573	11.26
c2	I	729	13.3	713	98.1	182	531	12.13
c2	0	729	13.5	710	97.7	163	546	10.82
Dl	I	732	10.7	720	98.8	190	532	13.40
Dl	0	732	10.7	715	98.0	175	542	12.35
D2	I	730	12.8	703	96.8	228	476	15.36
D2	0	729	13.2	684	94.2	193	494	12.89
El	I	733	10.5	706	96.6	184	522	13.04
El	0	733	10.5	700	95.9	172	529	12.19
E2	I	731	11.5	732	100.5	179	556	12.40
E2	0	730	11.6	723	99.4	162	563	11.20
Fl	I	733	10.6	685	93.8	201	485	14.21
Fl	0	732	10.6	670	91.7	173	498	12.23
F2	I	730	11.8	717	98.5	185	533	12.74
F2	0	730	12.1	705	97.0	156	551	10.67
Gl	I	732	10.7	668	91.4	219	449	15.45
Gl	0	732	10.8	653	89.3	189	464	13.30
G2	I	730	12.6	689	94.8	191	499	12.92
G2	0	730	12.8	684	94.1	165	520	11.11

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
08/25/93								
Al	I	737	10.0	743	101.1	151	593	10.82
Al	0	737	9.8	736	100.2	142	593	10.22
A2	I	736	11.6	745	101.6	150	596	10.37
A2	0	736	11.4	715	97.6	138	579	9.58
Bl	I	737	10.0	743	101.1	151	593	10.82
Bl	0	737	9.9	741	100.9	145	597	10.42
B2	I	736	11.6	745	101.6	150	596	10.37
B2	0	736	11.5	738	100.8	144	596	9.98
Cl	I	737	9.5	737	100.2	172	567	12.47
Cl	0	737	9.7	739	100.5	157	585	11.33
c2	I	736	12.1	719	98.2	182	539	12.45
c2	0	736	12.4	715	97.6	165	551	11.21
Dl	I	737	9.4	728	99.1	194	536	14.10
Dl	0	738	9.4	721	98.1	174	548	12.64
D2	I	736	11.0	707	96.5	231	478	16.19
D2	0	736	11.3	695	94.8	189	506	13.16
El	I	738	9.0	713	96.8	184	530	13.50
El	0	738	9.0	705	95.9	169	538	12.40
E2	I	736	10.0	737	100.3	176	562	12.61
E2	0	736	10.1	730	99.4	165	565	11.80
Fl	I	738	9.1	696	94.5	203	492	14.85
Fl	0	738	9.2	682	92.6	174	509	12.70
F2	I	736	10.3	723	98.5	182	542	12.96
F2	0	736	10.5	713	97.2	165	550	11.69
Gl	I	737	9.3	673	91.4	215	458	15.66
Gl	0	737	9.3	657	89.3	194	463	14.13
G2	I	737	10.7	691	94.2	195	497	13.76
G2	0	736	11.0	683	93.1	179	505	12.54

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
09/01/93								
Al	I	732	11.8	737	101.1	151	587	10.40
Al	0	732	11.6	728	99.9	140	588	9.68
A2	I	731	14.3	740	101.7	150	593	9.79
A2	0	731	14.1	730	100.3	134	596	8.78
Bl	I	732	11.8	737	101.1	151	587	10.40
Bl	0	732	11.8	732	100.4	144	589	9.91
B2	I	731	14.3	740	101.7	150	593	9.79
B2	0	730	14.3	736	101.2	143	593	9.33
Cl	I	732	11.5	731	100.1	171	562	11.85
Cl	0	732	11.5	731	100.2	161	571	11.16
c2	I	731	13.5	714	98.1	186	529	12.34
c2	0	731	13.8	710	97.7	173	539	11.41
Dl	I	732	11.3	717	98.2	197	522	13.71
Dl	0	732	11.3	709	97.1	179	531	12.46
D2	I	732	13.1	701	96.3	233	470	15.59
D2	0	732	13.4	681	93.5	189	491	12.57
El	I	734	11.0	707	96.9	186	521	13.03
El	0	733	11.0	697	95.5	170	526	11.91
E2	I	732	11.9	732	100.4	176	556	12.09
E2	0	732	12.1	718	98.5	159	560	10.87
Fl	I	733	11.0	685	93.8	200	484	14.01
Fl	0	732	11.1	666	91.2	168	499	11.75
F2	I	732	12.3	715	98.2	178	539	12.12
F2	0	731	12.5	702	96.4	156	547	10.58
Gl	I	732	11.1	662	90.6	209	454	14.61
Gl	0	732	11.2	646	88.4	180	466	12.56
G2	I	732	12.8	685	94.1	187	500	12.60
G2	0	731	13.0	674	92.5	167	510	11.20

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
09/08/93								
Al	I	735	13.2	742	101.4	155	586	10.35
Al	0	735	13.0	726	99.4	140	588	9.39
A2	I	733	15.3	734	100.9	153	586	9.78
A2	0	732	15.3	715	98.2	136	580	8.69
Bl	I	735	13.2	742	101.4	155	586	10.35
Bl	0	735	13.2	738	100.9	148	590	9.88
B2	I	733	15.3	734	100.9	153	586	9.78
B2	0	732	15.4	733	100.6	145	588	9.25
Cl	I	735	12.6	730	99.7	177	555	11.97
Cl	0	735	12.8	727	99.3	157	572	10.58
c2	I	732	15.1	708	97.1	206	503	13.22
c2	0	732	15.3	705	96.8	183	523	11.70
Dl	I	735	12.3	712	97.2	226	482	15.39
Dl	0	735	12.7	693	94.6	175	517	11.81
D2	I	731	14.8	703	96.6	238	467	15.37
D2	0	732	15.1	667	91.5	197	471	12.64
El	I	737	12.2	712	97.0	186	523	12.69
El	0	736	12.1	696	94.8	174	523	11.90
E2	I	734	13.3	730	99.8	187	544	12.46
E2	0	733	13.5	716	98.0	165	551	10.95
Fl	I	736	12.1	685	93.3	203	482	13.88
Fl	0	736	12.2	652	88.8	162	491	11.06
F2	I	733	13.8	708	97.1	186	524	12.26
F2	0	733	14.0	691	94.7	160	532	10.51
Gl	I	735	12.2	663	90.3	223	440	15.22
Gl	0	735	12.3	640	87.4	179	460	12.19
G2	I	733	14.2	685	93.8	195	490	12.75
G2	0	732	14.2	664	91.0	164	500	10.72

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
09/15/93								
Al	I	733	11.1	740	101.3	156	585	10.91
Al	0	733	11.0	727	99.5	138	591	9.67
A2	I	731	12.3	737	101.2	151	588	10.28
A2	0	731	12.3	709	97.3	127	584	8.65
Bl	I	733	11.1	740	101.3	156	585	10.91
Bl	0	733	11.1	735	100.8	145	591	10.14
B2	I	731	12.3	737	101.2	151	588	10.28
B2	0	731	12.3	730	100.2	144	588	9.81
Cl	I	733	10.5	729	99.8	178	548	12.61
Cl	0	733	10.6	729	99.8	163	569	11.53
c2	I	731	12.1	703	96.6	198	506	13.54
c2	0	731	12.3	701	96.2	179	522	12.19
Dl	I	733	10.4	705	96.6	227	482	16.12
Dl	0	733	10.5	698	95.5	200	499	14.17
D2	I	732	11.9	703	96.5	268	436	18.41
D2	0	731	12.1	672	92.2	222	452	15.18
El	I	733	10.4	721	98.5	182	538	12.93
El	0	734	10.4	708	96.8	165	546	11.72
E2	I	732	11.3	726	99.5	185	543	12.88
E2	0	731	11.4	713	97.9	162	552	11.25
Fl	I	734	10.4	697	95.3	204	493	14.49
Fl	0	733	10.5	669	91.5	166	504	11.76
F2	I	732	11.4	709	97.3	189	522	13.13
F2	0	732	11.6	696	95.4	156	542	10.79
Gl	I	733	10.6	677	92.4	280	397	19.80
Gl	0	733	10.5	654	98.4	217	439	15.38
G2	I	732	11.8	685	94.0	247	440	17.00
G2	0	731	11.9	671	92.0	209	462	14.36

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
09/22/93								
Al	I	735	7.1	738	100.7	152	588	11.66
Al	0	734	7.0	730	99.6	140	592	10.77
A2	I	733	9.6	740	101.3	152	570	10.99
A2	0	733	9.5	719	98.6	136	585	9.86
B1	I	735	7.1	738	100.7	152	588	11.66
B1	0	735	7.0	735	100.4	145	590	11.15
B2	I	733	9.6	740	101.3	152	570	10.99
B2	0	733	9.6	735	100.8	144	593	10.42
Cl	I	735	6.8	730	99.6	185	741	14.30
Cl	0	734	6.9	731	99.8	166	565	12.80
c2	I	733	9.3	709	97.1	202	508	14.71
c2	0	733	9.4	707	97.0	188	520	13.66
D1	I	734	6.6	708	96.7	222	488	17.24
D1	0	734	6.8	705	96.2	201	506	15.53
D2	I	732	9.2	710	97.3	275	437	20.08
D2	0	733	9.3	692	94.8	220	463	16.02
El	I	737	7.2	713	97.1	193	521	14.77
El	0	737	7.0	703	95.8	173	531	13.31
E2	I	734	7.3	728	99.4	188	541	14.36
E2	0	734	7.3	719	98.3	164	557	12.52
F1	I	736	6.8	693	94.5	223	470	17.24
F1	0	735	6.7	677	92.3	192	485	14.88
F2	I	733	7.5	717	98.0	197	520	14.97
F2	0	734	7.6	705	96.4	169	539	12.81
G1	I	734	6.7	672	91.6	274	399	21.23
G1	0	734	6.6	655	89.3	237	420	18.41
G2	I	734	7.8	696	95.1	234	462	17.66
G2	0	734	8.1	682	93.3	221	461	16.56

Appendix B (continued)

10/06/93

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-po2	DO ppm
Al	I	734	11.5	735	100.4	153	575	10.60
Al	0	734	11.5	723	98.7	137	588	9.49
A2	I	734	11.9	738	100.8	152	588	10.44
A2	0	734	11.8	723	98.8	140	583	9.64
B1	I	734	11.5	735	100.4	153	575	10.60
B1	0	734	11.5	729	99.6	144	586	9.98
B2	I	734	11.9	738	100.8	152	588	10.44
B2	0	734	11.9	733	100.1	146	588	10.03
Cl	I	734	11.1	725	99.1	184	541	12.86
Cl	0	734	11.4	723	98.9	163	561	11.32
c2	I	734	11.8	699	95.5	211	488	14.53
c2	0	734	11.8	699	95.5	197	502	13.56
D1	I	733	11.1	707	96.6	202	495	14.12
D1	0	733	11.2	691	94.3	171	521	11.93
D2	I	734	11.8	700	95.5	273	429	18.79
D2	0	734	11.8	659	90.0	204	455	14.04
El	I	734	10.4	722	98.8	174	550	12.36
El	0	734	10.5	704	96.2	151	556	10.70
E2	I	735	11.6	732	100.1	184	544	12.72
E2	0	734	11.6	722	98.6	166	557	11.48
F1	I	734	10.7	701	95.8	211	490	14.89
F1	0	733	10.7	680	92.8	162	518	11.43
F2	I	734	11.2	714	97.6	187	529	13.05
F2	0	734	11.7	700	95.6	157	543	10.83
G1	I	733	10.8	674	92.1	261	412	18.37
G1	0	733	10.8	649	88.7	190	460	13.37
G2	I	734	11.8	684	93.3	218	467	15.01
G2	0	734	11.8	665	90.8	187	479	12.87

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	PO2	Pt-pO2	Do ppm
10/11/93								
Al	I	732	10.1	743	101.7	152	591	10.87
Al	0	732	10.0	736	99.9	140	596	10.03
A2	I	732	10.8	745	102.1	151	594	10.63
A2	0	732	10.6	715	98.1	134	581	9.47
B1	I	732	10.1	743	101.7	152	591	10.87
B1	0	732	10.1	736	100.8	145	591	10.37
B2	I	732	10.8	745	102.1	151	594	10.63
B2	0	732	10.7	739	101.4	145	594	10.23
Cl	I	732	9.8	734	100.6	175	559	12.60
Cl	0	732	9.9	734	100.6	167	567	12.00
c2	I	731	10.5	701	97.4	206	495	14.60
c2	0	732	10.5	703	96.4	181	522	12.83
D1	I	732	9.7	709	97.0	206	503	14.87
D1	0	732	9.8	693	94.9	171	522	12.31
D2	I	732	10.2	718	98.3	267	451	19.05
D2	0	732	10.4	678	92.8	222	456	15.77
El	I	732	9.4	723	99.1	182	541	13.23
El	0	732	9.4	707	96.9	160	547	11.63
E2	I	732	9.6	733	100.3	180	553	13.02
E2	0	732	9.6	723	99.0	165	558	11.94
F1	I	731	9.5	696	95.3	209	487	15.15
F1	0	732	9.5	681	93.2	177	504	12.83
F2	I	732	9.6	721	98.7	188	533	13.60
F2	0	732	9.6	703	96.2	171	532	12.37
G1	I	731	9.5	673	92.1	245	428	17.76
G1	0	732	9.6	647	88.5	213	434	15.41
G2	I	732	9.7	690	94.3	221	469	15.95
G2	0	732	9.7	673	92.1	200	473	14.43

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
10/18/93								
Al	I	736	7.1	731	99.5	150	581	11.51
Al	0	737	7.9	725	98.9	136	589	10.24
A2	I	736	8.7	729	99.5	151	578	11.15
A2	0	736	8.6	724	99.0	141	583	10.44
B1	I	736	7.1	731	99.5	150	581	11.51
B1	0	736	8.1	727	99.2	146	581	10.94
B2	I	736	8.7	729	99.5	151	578	11.15
B2	0	736	8.7	728	99.2	144	584	10.64
Cl	I	737	7.7	722	98.3	178	544	13.46
Cl	0	736	7.8	724	98.8	164	560	12.37
c2	I	736	8.3	725	99.0	202	523	15.06
c2	0	736	8.6	724	98.8	193	531	14.29
D1	I	737	7.5	711	96.9	198	513	15.05
D1	0	737	7.6	712	96.9	172	540	13.04
D2	I	735	8.2	732	99.7	262	470	19.58
D2	0	736	8.4	726	99.1	212	514	15.77
El	I	738	7.7	732	99.6	187	545	14.14
El	0	737	7.7	708	96.3	171	537	12.93
E2	I	736	7.5	707	96.3	178	529	13.53
E2	0	736	7.6	713	97.1	162	551	12.28
F1	I	736	7.7	703	97.0	216	487	16.34
F1	0	737	7.7	709	96.5	188	521	14.22
F2	I	736	7.6	716	97.4	184	532	13.95
F2	0	737	7.6	716	97.4	166	550	12.58
G1	I	737	7.8	704	95.8	244	460	18.41
G1	0	737	7.8	691	94.0	216	475	16.30
G2	I	737	7.6	712	96.9	208	504	15.77
G2	0	736	7.7	709	96.5	192	517	14.52

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
10/28/93								
Al	I	738	6.5	734	99.8	152	582	11.83
Al	0	738	6.4	737	98.7	142	595	11.08
A2	I	736	8.0	724	98.7	151	573	11.34
A2	0	736	7.9	712	97.1	141	571	10.61
B1	I	738	6.5	734	99.8	152	582	11.83
B1	0	738	6.5	731	99.3	148	583	11.52
B2	I	736	8.0	724	98.7	151	573	11.34
B2	0	736	8.0	717	97.8	144	573	10.81
Cl	I	738	6.2	720	97.7	177	543	13.88
Cl	0	738	6.3	725	98.5	166	559	12.99
c2	I	735	7.8	706	96.3	199	507	15.01
c2	0	736	8.0	708	96.5	190	518	14.27
D1	I	738	6.0	709	96.2	205	504	16.16
D1	0	738	6.1	710	96.4	170	540	13.37
D2	I	737	7.6	710	96.8	259	451	19.63
D2	0	737	7.7	699	95.2	208	491	15.73
El	I	740	6.8	719	97.5	190	529	14.68
El	0	740	6.7	708	95.9	168	540	13.02
E2	I	738	6.6	736	100.0	182	554	14.14
E2	0	737	6.9	732	99.6	164	568	12.64
F1	I	738	6.6	705	95.6	212	493	16.47
F1	0	738	6.3	698	94.6	184	514	14.40
F2	I	737	7.0	731	99.4	188	543	14.46
F2	0	737	7.4	726	98.8	166	560	12.65
G1	I	738	6.2	690	93.6	233	457	18.27
G1	0	738	6.0	681	92.3	200	481	15.76
G2	I	737	7.5	719	97.8	189	530	14.36
G2	0	737	7.5	707	96.3	173	534	13.15

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
11/03/93								
Al	I	740	5.4	732	99.2	151	581	12.08
Al	0	739	5.3	725	98.2	142	583	11.39
B1	I	739	5.4	732	99.2	151	581	12.08
B1	0	739	5.4	729	98.7	147	582	11.76
Cl	I	739	5.2	719	97.4	176	543	14.15
Cl	0	739	5.3	724	98.0	169	555	13.55
c2	I	739	5.8	714	96.3	196	518	15.53
c2	0	739	5.9	713	96.6	187	526	14.78
D1	I	739	5.2	708	95.9	192	516	15.44
D1	0	739	5.2	710	96.3	172	538	13.83
D2	I	739	5.7	714	96.8	257	457	20.41
D2	0	739	5.8	708	95.8	214	494	16.95
El	I	741	5.0	717	97.3	187	530	15.11
El	0	741	5.0	709	96.0	168	541	13.58
E2	I	739	5.5	735	99.4	176	559	14.05
E2	0	739	5.5	734	99.4	165	569	13.17
F1	I	741	5.0	706	95.6	207	499	16.73
Fi	0	741	5.0	700	94.8	180	520	14.55
F2	I	739	5.5	733	99.4	186	547	14.84
F2	0	739	5.6	730	98.9	172	558	13.69
G1	I	740	5.1	691	93.6	220	471	17.73
G1	0	739	5.1	670	91.8	200	470	16.12
G2	I	739	5.6	723	97.9	199	524	15.84
G2	0	739	5.7	712	96.4	182	530	14.45

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	Do ppm
11/10/93								
Al	I	733	5.1	722	98.5	152	570	12.25
Al	0	733	5.1	715	97.3	138	577	11.12
A2	I	733	5.2	723	98.8	151	572	12.14
A2	0	731	5.1	711	97.1	143	568	11.53
B1	I	733	5.1	722	98.5	152	570	12.25
B1	0	733	5.1	718	97.7	143	575	11.53
B2	I	733	5.2	723	98.8	151	572	12.14
B2	0	732	5.1	715	97.8	148	567	11.93
Cl	I	733	4.9	711	96.9	179	532	14.50
Cl	0	733	4.9	713	97.1	170	543	13.77
c2	I	732	5.1	704	96.3	184	520	14.83
c2	0	731	5.1	706	96.6	177	529	14.27
D1	I	733	4.7	703	95.8	170	533	13.84
D1	0	733	4.8	706	96.1	154	552	12.51
D2	I	733	5.0	707	96.4	221	486	17.86
D2	0	732	5.1	702	95.9	185	517	14.91
El	I	736	4.7	716	97.4	173	543	14.09
El	0	736	4.5	709	96.6	163	546	13.34
E2	I	733	5.1	725	99.0	172	553	13.86
E2	0	733	5.2	723	98.7	158	565	12.70
F1	I	735	4.5	700	95.5	186	514	15.22
F1	0	734	4.5	694	94.8	171	523	13.99
F2	I	731	5.2	722	98.6	172	550	13.83
F2	0	732	5.2	719	98.2	158	561	12.70
G1	I	734	4.5	687	93.6	200	487	16.37
G1	0	734	4.5	677	92.3	168	509	13.75
G2	I	732	5.1	710	97.0	182	528	14.67
G2	0	733	5.0	704	96.1	168	536	13.58

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	Do ppm
11/17/93								
Al	I	734	6.0	724	98.6	149	575	11.74
Al	0	734	5.9	713	97.1	135	578	10.67
A2	I	733	5.8	724	98.4	151	574	11.96
A2	0	733	5.7	714	97.1	142	473	11.28
B1	I	734	6.0	724	98.6	149	575	11.74
B1	0	734	5.9	719	97.8	142	578	11.22
B2	I	733	5.8	724	98.4	151	574	11.96
B2	0	734	5.7	720	97.8	147	574	11.67
Cl	I	734	5.9	713	97.1	176	538	13.91
Cl	0	734	5.9	712	96.9	168	545	13.27
c2	I	733	5.6	708	96.3	179	530	14.25
c2	0	733	5.6	710	96.5	171	540	13.61
D1	I	734	6.0	709	96.5	173	536	13.64
D1	0	734	6.0	711	96.8	147	564	11.59
D2	I	733	5.5	696	94.5	188	510	15.00
D2	0	733	5.5	700	95.1	170	531	13.57
El	I	734	5.5	724	98.6	170	555	13.57
El	0	734	5.5	716	97.5	160	558	12.77
E2	I	733	5.8	727	98.8	171	556	13.54
E2	0	733	5.9	725	98.6	158	569	12.48
F1	I	734	5.5	705	96.2	184	523	14.68
F1	0	733	5.5	696	94.8	163	533	13.01
F2	I	734	5.9	724	98.6	172	554	13.59
F2	0	734	5.9	720	98.0	158	563	12.48
G1	I	733	5.5	684	93.0	195	488	15.56
G1	0	733	5.5	675	91.8	171	504	13.65
G2	I	733	6.0	709	96.5	182	528	14.34
G2	0	734	6.0	701	95.4	166	535	13.08

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
11/23/93								
Al	I	739	3.1	728	98.3	156	575	13.24
Al	0	739	3.0	721	97.8	146	578	12.42
A2	I	740	3.0	728	98.1	151	580	12.85
A2	0	740	3.1	721	97.1	144	579	12.22
B1	I	739	3.1	728	98.3	156	575	13.24
B1	0	739	3.1	726	97.8	152	575	12.90
B2	I	740	3.0	728	98.1	151	580	12.85
B2	0	740	3.1	725	97.5	147	500	12.47
Cl	I	739	2.9	721	97.4	178	544	15.18
Cl	0	739	3.0	721	97.3	171	551	14.55
c2	I	740	3.1	716	96.4	176	541	14.93
c2	0	740	3.1	718	96.6	169	550	14.34
D1	I	738	2.8	711	95.5	186	525	15.91
D1	0	739	2.9	723	97.9	156	568	13.31
D2	I	740	3.1	713	96.1	183	531	15.53
D2	0	740	3.1	713	96.1	165	549	14.00
El	I	739	2.9	726	98.2	174	554	14.84
El	0	738	2.8	723	97.8	165	559	14.11
E2	I	739	3.1	732	98.6	170	564	14.42
E2	0	739	3.1	730	98.4	161	571	13.66
F1	I	738	2.8	715	96.5	187	528	15.99
F1	0	738	2.8	708	95.4	172	536	14.71
F2	I	739	3.1	729	98.3	176	556	14.93
F2	0	739	3.2	727	98.1	160	568	13.54
G1	I	738	2.8	698	93.9	200	498	17.10
G1	0	738	2.8	690	92.8	182	508	15.56
G2	I	740	3.2	718	96.8	185	535	15.66
G2	0	740	3.1	708	95.4	170	539	14.42

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
12/01/93								
Al	I	735	5.5	729	98.9	150	579	11.97
Al	0	736	5.4	722	97.6	141	581	11.28
A2	I	739	5.9	728	98.2	151	577	11.93
A2	0	738	5.8	719	97.0	144	575	11.41
B1	I	735	5.5	729	98.9	150	579	11.97
B1	0	736	5.4	729	99.0	146	583	11.68
B2	I	739	5.9	728	98.2	151	577	11.93
B2	0	739	5.9	723	97.6	146	577	11.54
Cl	I	736	5.4	720	97.5	175	545	14.00
Cl	0	736	5.4	720	97.5	167	553	13.36
c2	I	737	5.7	713	96.4	177	536	14.05
c2	0	738	5.8	716	96.8	171	545	13.54
D1	I	736	5.4	715	96.9	175	540	14.00
D1	0	736	5.4	717	97.1	148	569	11.84
D2	I	736	5.6	708	96.0	183	525	14.57
D2	0	736	5.6	707	95.9	164	543	13.06
El	I	736	5.3	732	99.4	170	562	13.63
Ei	0	737	5.3	724	98.4	160	564	12.83
E2	I	736	5.5	729	98.8	171	558	13.65
E2	0	736	5.5	726	98.5	153	573	12.21
F1	I	736	5.3	717	95.8	185	532	14.84
F1	0	736	5.3	704	95.8	165	539	13.23
F2	I	735	5.5	723	98.1	169	554	13.49
F2	0	735	5.6	720	97.6	154	566	12.26
G1	I	736	5.4	694	94.3	191	503	15.28
G1	0	736	5.4	683	92.7	175	508	14.00
G2	I	736	5.6	708	95.8	178	530	14.17
G2	0	736	5.6	703	95.2	165	538	13.13

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
01/21/94								
Al	I	733	5.3	737	100.8	153	584	12.27
Al	0	733	5.1	729	99.5	145	584	11.69
A2	I	732	6.1	734	100.4	152	584	11.95
A2	0	731	5.9	721	98.7	141	580	11.14
B1	I	733	5.3	737	100.8	153	584	12.27
B1	0	733	5.1	733	100.1	148	586	11.93
B2	I	732	6.1	734	100.4	152	584	11.95
B2	0	731	6.0	731	100.0	148	584	11.67
Cl	I	733	5.0	731	99.8	172	559	13.90
Cl	0	733	5.1	729	99.5	164	565	13.22
c2	I	731	5.8	720	98.5	178	543	14.10
c2	0	731	5.8	716	97.9	172	545	13.62
D1	I	733	4.9	729	99.6	173	557	14.02
D1	0	733	5.0	717	98.0	153	564	12.36
D2	I	731	5.7	728	99.5	181	548	14.37
D2	0	731	5.7	718	98.3	166	553	13.18
El	I	732	4.7	725	99.1	173	552	14.09
El	0	732	4.7	716	98.0	164	553	13.35
E2	I	733	5.5	732	100.0	172	560	13.73
E2	0	732	5.5	723	98.9	160	564	12.77
F1	I	731	4.8	697	95.4	188	510	15.27
F1	0	732	4.8	687	94.0	161	525	13.08
F2	I	732	5.5	720	98.4	174	547	13.89
F2	0	732	5.5	711	97.3	152	559	12.13
G1	I	732	4.8	674	92.1	199	475	16.16
G1	0	732	7.8	650	88.9	177	474	13.35
G2	I	732	5.6	689	94.2	180	509	14.33
G2	0	731	5.6	679	92.8	168	511	13.37

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
01/26/94								
Al	I	734	3.8	737	100.6	153	584	12.75
Al	0	734	3.7	731	99.6	147	584	12.28
A2	I	734	4.4	7.6	100.6	152	585	12.47
A2	0	734	4.4	731	99.9	145	586	11.90
B1	I	734	3.8	737	100.6	153	584	12.75
B1	0	734	3.8	733	100.1	148	586	12.33
B2	I	734	4.4	7.6	100.6	152	585	12.47
B2	0	734	4.4	734	100.3	149	586	12.22
Cl	I	734	3.6	731	99.7	175	557	14.66
Cl	0	734	3.7	730	99.6	164	566	13.70
c2	I	734	4.2	722	98.6	184	540	15.17
c2	0	734	4.3	718	98.0	170	548	13.98
D1	I	734	3.6	728	99.2	181	548	15.16
D1	0	734	3.6	719	98.1	157	563	13.15
D2	I	734	4.2	729	99.6	183	548	15.09
D2	0	734	4.2	735	99.1	170	555	14.02
El	I	735	3.6	725	99.0	172	553	14.40
El	0	735	3.6	720	98.2	159	561	13.32
E2	I	734	3.8	732	99.9	169	562	14.08
E2	0	734	4.0	728	99.4	159	159	13.18
F1	I	734	3.6	697	95.1	187	510	15.66
F1	0	734	3.6	688	93.8	168	520	14.07
F2	I	734	4.0	724	98.9	174	174	14.42
F2	0	734	4.0	718	98.0	161	558	13.35
G1	I	734	3.6	670	91.4	198	472	16.58
G1	0	734	3.6	656	89.4	182	473	15.24
G2	I	734	4.1	690	94.2	183	507	15.13
G2	0	734	4.1	682	93.1	172	510	14.22

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	Do ppm
02/02/94								
Al	I	734	2.1	735	100.2	152	582	13.24
Al	0	734	2.0	730	99.6	147	583	12.84
A2	I	731	2.7	734	100.6	152	583	13.03
A2	0	730	2.6	728	99.8	144	586	12.38
B1	I	734	2.1	735	100.2	152	582	13.24
B1	0	734	2.1	732	99.9	148	585	12.89
B2	I	731	2.7	734	100.6	152	583	13.03
B2	0	731	2.6	732	100.3	148	585	12.72
Cl	I	734	1.9	729	99.3	170	560	14.89
Cl	0	734	1.9	730	99.5	167	563	14.63
c2	I	732	2.4	721	98.8	176	546	15.21
c2	0	731	2.5	721	98.8	172	550	14.83
D1	I	735	2.0	727	99.1	170	556	14.85
D1	0	734	2.0	722	98.3	161	561	14.06
D2	I	732	2.3	726	99.3	190	538	16.46
D2	0	731	2.4	723	99.0	170	553	14.69
El	I	737	2.1	725	98.7	174	552	15.16
El	0	736	2.1	722	98.1	167	555	14.55
E2	I	734	2.1	728	99.5	169	560	14.72
E2	0	734	2.1	725	98.9	160	565	13.94
F1	I	736	2.1	698	94.9	182	515	15.85
F1	0	736	2.1	691	93.9	164	527	14.29
F2	I	733	2.2	721	98.6	171	551	14.86
F2	0	733	2.2	715	97.7	159	557	13.81
G1	I	736	2.1	674	91.7	188	485	16.38
G1	0	735	2.1	659	89.8	168	491	14.64
G2	I	733	2.3	689	94.2	178	511	15.42
G2	0	733	2.3	683	93.3	168	515	14.56

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-pO2	DO ppm
02/09/94								
Al	I	734	3.0	735	100.3	152	583	12.93
Al	0	733	2.9	728	99.3	142	585	12.11
A2	I	734	3.5	738	100.7	151	587	12.68
A2	0	734	3.4	730	99.5	143	586	12.04
B1	I	734	3.0	735	100.3	152	583	12.93
B1	0	734	2.9	731	99.8	146	585	12.45
B2	I	734	3.5	738	100.7	151	587	12.68
B2	0	734	3.4	734	100.1	147	588	12.38
Cl	I	733	2.8	730	99.6	170	560	14.54
Cl	0	734	2.9	728	99.4	164	564	13.99
c2	I	734	3.4	722	98.5	177	545	14.90
c2	0	734	3.4	719	98.2	171	549	14.40
D1	I	734	2.8	729	99.4	175	552	14.97
D1	0	734	2.8	726	99.0	163	563	13.94
D2	I	734	3.3	728	99.3	193	535	16.29
D2	0	734	3.3	722	98.6	172	552	14.52
El	I	734	2.7	721	98.5	172	549	14.75
El	0	734	2.7	719	98.2	164	556	14.06
E2	I	734	3.0	731	99.7	171	560	14.55
E2	0	734	3.1	725	98.9	162	563	13.75
F1	I	734	2.7	696	95.0	179	517	15.35
F1	0	734	2.7	687	93.8	159	529	13.63
F2	I	734	3.2	724	98.8	172	551	14.56
F2	0	734	3.2	718	97.9	153	565	12.95
G1	I	733	2.8	674	91.9	186	487	15.91
G1	0	733	2.8	657	89.7	166	491	14.20
G2	I	733	3.3	690	94.2	177	512	14.94
G2	0	733	3.3	684	93.3	166	518	14.01

Appendix B (continued)

Group	I/O	Bar	Temp C	Pt	% SAT	pO2	Pt-po2	DO ppm
02/16/94								
Al	I	721	4.6	736	100.9	154	573	12.57
Al	0	721	4.5	717	99.6	140	577	11.46
A2	I	718	5.6	721	100.8	150	571	11.94
A2	0	718	5.5	715	99.8	143	573	11.41
B1	I	721	4.6	736	100.9	154	573	12.57
B1	0	721	4.6	719	99.9	143	577	11.67
B2	I	718	5.6	721	100.8	150	571	11.94
B2	0	718	5.5	718	100.3	147	572	11.73
Cl	I	722	4.4	720	100	173	547	14.19
Cl	0	721	4.4	720	100	167	553	13.7
c2	I	718	5.5	707	98.7	176	538	14.05
c2	0	718	5.5	705	98.3	170	532	13.57
D1	I	722	4.2	716	99.4	176	541	14.51
D1	0	722	4.3	710	98.7	161	550	13.24
D2	I	718	5.4	712	99.4	182	531	14.56
D2	0	718	5.4	702	98	164	537	13.12
El	I	723	4.1	711	98.6	174	537	14.39
El	0	723	4.1	705	97.7	166	539	13.72
E2	I	719	4.9	718	100.1	168	550	13.61
E2	0	719	5.0	713	99.4	161	553	13.01
F1	I	722	4.1	684	94.8	182	502	15.05
F1	0	722	4.1	674	93.4	165	509	13.64
F2	I	719	5.1	708	98.8	172	538	13.86
F2	0	718	5.2	699	97.6	153	546	12.3
G1	I	722	4.2	658	91.2	188	471	15.5
G1	0	721	4.2	645	98.5	168	478	13.85
G2	I	718	5.3	674	93.9	174	500	i3.96
G2	0	718	5.3	664	92.6	159	505	12.75

APPENDIX C

Water Chemistry Data Collected at Dexter Holding Pond, 1993-1994. Suspended solids are in **mg/L,** ammonia is **ug/L,** and alkalinity is in ppm.

Date	pH		Suspended solids		Ammonia		Alkalinity
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	
10/19/93	7.24	7.27	1.0	1.2	0.04	0.12	27.5
12/10/93	7.63	7.58	1.7	2.2	0.10	0.14	28.1
01/14/94	7.45	7.44	1.7	2.3	0.16	0.14	26.3
01/28/94	7.43	7.44	0.8	1.3	0.12	0.12	- - -
02/11/94	7.31	7.32	1.6	2.2	0.07	0.12	25.7

APPENDIX D

Dissolved Gas Readings Taken at the Inflow (I) and Outflow (0)
of Dexter Holding Pond, 1993-1994.

Date	I/O	Bar	Temp	Pt	% Sat	pO2	pt-p02	ppm
10/19/93	I	758	11.1	733	95.4	134	601	9.37
	0	760	11.1	728	95.4	131	597	9.16
01/28/94	I	755	6.0	749	99.5	149	602	11.74
	O	755	6.0	742	98.6	148	595	11.67
02/11/94	I	757	5.1	743	98.4	156	588	12.57
	0	757	5.1	737	97.6	146	590	11.77