



Effect of Lowered Temperature on Growth of Juvenile Nechako River Chinook Salmon (*Oncorhynchus tshawytscha*) at Three Ration Levels

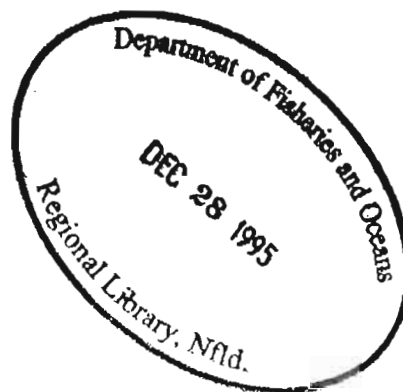
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1995

EFFECT OF LOWERED TEMPERATURE ON GROWTH OF JUVENILE NECHAKO RIVER
CHINOOK SALMON (*Oncorhynchus tshawytscha*) AT THREE RATION LEVELS

by

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Can. Data Rep. Fish. Aquat. Sci. 958:21p.

ABSTRACT

Shelbourn, John E., W. Craig Clarke and C. D. Levings. 1995.
Effect of lowered temperature on growth of juvenile Nechako
River chinook salmon (*Oncorhynchus tshawytscha*) at three
ration levels. Can. Data Rep. Fish. Aquat. Sci. 958:21p.

This report contains data on the growth performance of wild chinook salmon fry taken from the Nechako River, B.C. on 26 April, 1994. Fish were taken to a laboratory and fed a commercial diet to measured satiation, or a calculated 80 or 60% of satiation. Water temperature simulated the daily ambient river temperature, or ambient with a decrease to 15, 12.5 or 10°C for 30 days. Photoperiod was set daily to that at the river site. The experiment was terminated on 29 September. Full data tables of sample means of growth measurement are presented, with a calculation of feed conversion and ration. Figures illustrate experimental design and the results.

key words: chinook salmon, Nechako, temperature, ration, growth.

RÉSUMÉ

Shelbourn, John E., W. Craig Clarke and C. D. Levings. 1995.
Effet de l'abaissement de la température sur la croissance
de jeunes saumons quinnat (*Oncorhynchus tshawytscha*) de la
rivière Nechako étudié pour trois différentes rations
alimentaires. Can. Data Rep. Fish. Aquat. Sci. 958:21p.

Ce rapport présente les données obtenues en 1994 sur la performance de croissance de jeunes saumons quinnat sauvages, prises le 26 avril de la rivière Nechako, C.B. Les poissons transférés au laboratoire ont été nourris d'un aliment commercial à satiété ou à 60 ou 80% de la satiété. La température de l'eau a été ajustée à la température journalière de la rivière ou abaissée de 10, 12.5 ou 15°C et ce pendant 30 jours. La photopériode a été ajustée quotidiennement à celle du site étudié de la rivière. L'expérience a été terminée le 29 septembre. Les tableaux présentent les valeurs moyennes des mesures de croissance des différents échantillons ainsi que les calculs sur la transformation de la nourriture et la valeur de la ration. Les figures présentent les protocoles expérimentaux et les résultats.

mots-clés: saumons quinnat, Nechako, température, ration, croissance.

INTRODUCTION

The release of water from the proposed Kenney Dam Release Facility (KDRF) into the Nechako River to provide thermal control for returning adult sockeye salmon may affect resident juvenile chinook salmon in the river. In particular, the introduction of cool deep water from the reservoir will decrease river temperature in July and August, and thus may affect growth of pre-migratory juvenile chinook. The water released from the KDRF will cool the downstream reaches of the Nechako River, the degree of change depending on the water flow and temperature both in the river and in the release from the reservoir. This experiment provides an opportunity to examine the effects of temperature, at different levels of feed availability, on growth of underyearling chinook salmon in a controlled environment.

Chinook fry, captured in the Nechako River, were maintained in the laboratory at water temperatures adjusted daily to temperatures recorded in the Nechako River. In some treatments, the fish were subjected to a decrease in temperature between mid July and mid August, similar to that which would be caused by the release of cooling water into the Nechako River from the KDRF.

MATERIALS AND METHODS

Source of fish and acclimation

Chinook fry were trapped overnight on 26 April, 1994 by different methods at two locations in the Nechako River: by inclined plane trap at Irvine's Lodge below Cheslatta Falls, and by rotary trap at Diamond Island (60 km further downstream). The fry were placed in aerated, insulated containers and immediately trucked to Prince George. From there the containers were sent by air to the Department of Fisheries and Oceans (DFO), Pacific Biological Station (PBS) at Nanaimo on 27 April. The separate identity of the two sources of chinook fry was maintained throughout the experiment.

The fish were held in two sterilized 200 L culture tanks at PBS. The tanks were fitted with mixing valves to control water temperatures and had a central, self-cleaning drain. Cover was provided with a lid which was partially opaque, allowing shade for the fish.

Initially, temperatures were maintained daily according to the mean of river temperatures recorded at Irvine's Lodge from 1981 to 1993 (unpublished data from temperature monitoring archives of Habitat Management, DFO Canada, 555 West Hastings Street, Vancouver, BC. V6B 5G3)

Photoperiod was set daily to simulate daylight \pm civil twilight at the river (latitude 54°N, longitude 125°W: data courtesy Chris Aikman, DAO, NRC Canada, Saanich, BC. V8X 4M5).

After arrival at PBS, fish were hand fed several times daily to cessation of feeding, with automatic feeders being used on weekends. Fry were fed Biodiet® mash mixed with Murex® krill fines (krill fines were withdrawn on 16 June). Feed size was increased according to increasing fish size, following the manufacturer's advice.

A bulk sample of fish from each group was weighed and returned to the tanks on 27 May.

On 16 June all the fish were weighed and measured individually under light anesthetic (2-phenoxyethanol, 5 ppm solution), and returned to several similar tanks to avoid the possibility of overcrowding. After this distribution, Biodiet® became the exclusive feed.

On 4 and 5 July, fish were selected without known bias for tagging internally with passively induced transponder (PIT) tags (Prentice, 1990) and were distributed without choice to separate tanks according to the two collection sites and the feed and temperature regimes, as described in the paragraph below. The treatments had been randomly assigned to the tanks before the distribution of fish. To ensure that there were approximately 30 fish per tank (by experience an ideal number for these tanks), most were selected, including small fish. Fish were tagged by ventrolateral insertion of a PIT tag into the body cavity, using a sterilized 12 ga. hypodermic needle. However, fish under 2 grams were not selected if they appeared too frail to accept the hypodermic needle during tagging.

On the following day, 6 July, the experimental rationing of feed was started, based on the fish weights obtained. This was considered to be the first day of the experiment. The experimental design and treatments to be applied are shown in Table 1. The fish were fed by hand between 0800 and 1600 daily, to measured satiation (R_{\max}), or 80% ($R_{.8}$) or 60% ($R_{.6}$) of the R_{\max} tank with the same temperature regime. The $R_{.6}$ fish were fed every other day to ensure a full access to feed for all the fish. Temperature was recorded daily before any required adjustment. Water supplied to the laboratory at regulated temperatures, and was mixed according to the protocol for that treatment. Adjustments were made as necessary to maintain limits of $\pm 0.3^{\circ}\text{C}$.

Experimental protocol

Temperature regulation during the experiment is illustrated in Figure 1.

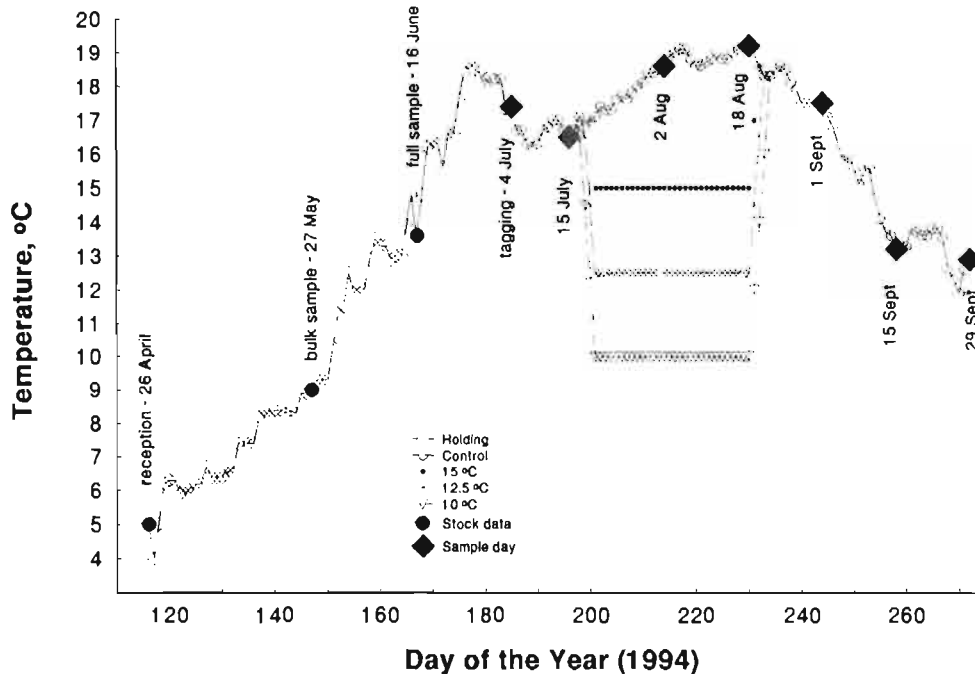


Figure 1. Protocol for daily setting of temperature level and the sampling schedule for chinook fry from receipt of fry on 26 April to termination of experiment on 29 September, 1994.

After tagging, the control temperature (ambient level) was set daily to follow the temperature recorded by DFO at Cheslatta Falls in 1992, from 15 July to 1 September. 1992 was a year of high temperature: this high level was chosen to set a naturally occurring upper limit to the design. The remaining tanks were regulated similarly, except that for a 30-day period (to produce the cooling effect of water release from the KDRF), levels were set at 10°C, 12.5°C and 15°C. These temperatures were to approximate the cooling anticipated by the change in water source. After this period (18 July to 18 August - allowing for 2°C per day acclimation), temperatures were restored to the control level. The experiment was terminated on 29 September. The mean of the daily temperature records over each sampling interval, for each group (tank), is presented in Table 2. Details of the sampling times and temperature adjustments are also presented graphically in Figure 1.

All the fish were sampled approximately every 15 days. After

the initial sampling of weight only (to avoid undue handling of fish at tagging) and until the end of the experiment, weight and length of each fish were obtained at each sampling.

During sampling, the fish were removed to an aerated pail, and each fish was then lightly anaesthetized in aerated water containing aerated 2-phenoxyethanol (5 ppm). Data were recorded electronically, using a laptop computer and software written by John Blackburn at PBS. For each fish, the PIT tag number was electronically identified and recorded, fork length was measured to 0.1 cm and the fish was immediately placed in an aerated bath of normal water at the appropriate temperature, which was placed on a self-taring balance, sensitive to 0.1 g. Weight was then automatically recorded. During this absence of fish, each empty tank was thoroughly cleaned and refilled.

For each fish, weight (W) was recorded in grams, length (L) in centimetres, condition factor was calculated as $100 \cdot (W \cdot L^{-3})$ and specific growth was computed as $100 \cdot (\ln W_n - \ln W_{n-1}) \cdot \Delta t^{-1}$, where Δt = interval in days.

After each weighing, ration was recalculated on a dry weight basis according to measured water content of some of the same stock of fish. Fish dry weight was obtained from sampling a tank of residual fish held at ambient temperature, fed at R_8 level (there was an insufficiency of stock to sample each tank). The samples were dried for 24h at 80°C. Feed dry weight was obtained at the same time. Proportional rations, based on dry weight of fish and feed, were derived from the feeding performance of the maximally fed fish at each of the appropriate temperatures: i.e., 80 and 60% of the ration was calculated according to the newly obtained biomass of these groups on reduced ration. Between samples, ration was adjusted daily according to a growth model provided by Bill McLean, Quinsam River Hatchery, Campbell River, BC (McLean, 1967).

DATA PRESENTATION

A full series of data tables is presented. The data pertaining to measurements taken on the sampling days are for all fish alive at that time (Tables 3 through 6: each of these tables spans 2 pages).

The daily mortality record is shown in Table 7. Measured biomass is recorded in Table 8, with estimation of weight on those occasions when fish died between samples. Data for feed conversion and ration (Tables 9 and 10) were based on biomass, using adjusted values when necessary in order to provide data on a per-fish basis. Instances where it was necessary to estimate

the weight of missing fish (because of mid-period mortality) are indicated in Table 8 by bold type, and in Tables 9 and 10 by an asterisk.

No infectious agents were found in any of the samples examined by the PBS Fish Health Unit. Two moribund fish from the group with excessive mortality (tank 501) were sectioned for histological examination. The resulting report indicated no evidence of significant pathology.

Figure 2 shows mean fish weight, one plot for each of the three ration levels and all to the same scale. The lines drawn are the average of the two sites for the four temperatures. Inspection of the three plots indicates a predominant effect of ration on growth. The decrease in growth in the maximally fed fish with temperature lowering (Fig. 2a), appeared to have been ameliorated by compensatory growth of these fish after temperature was restored to ambient. Such a response was not evident in the two groups on restricted ration (Fig 2, b and c).

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tagging and data monitoring. We thank Dominique Hervio for correcting the grammar of the résumé, and Gloria Bayntun for producing the final document. The Technical Committee of the NFCP provided criticism of the manuscript. Responsibility for the report remains with the senior author.

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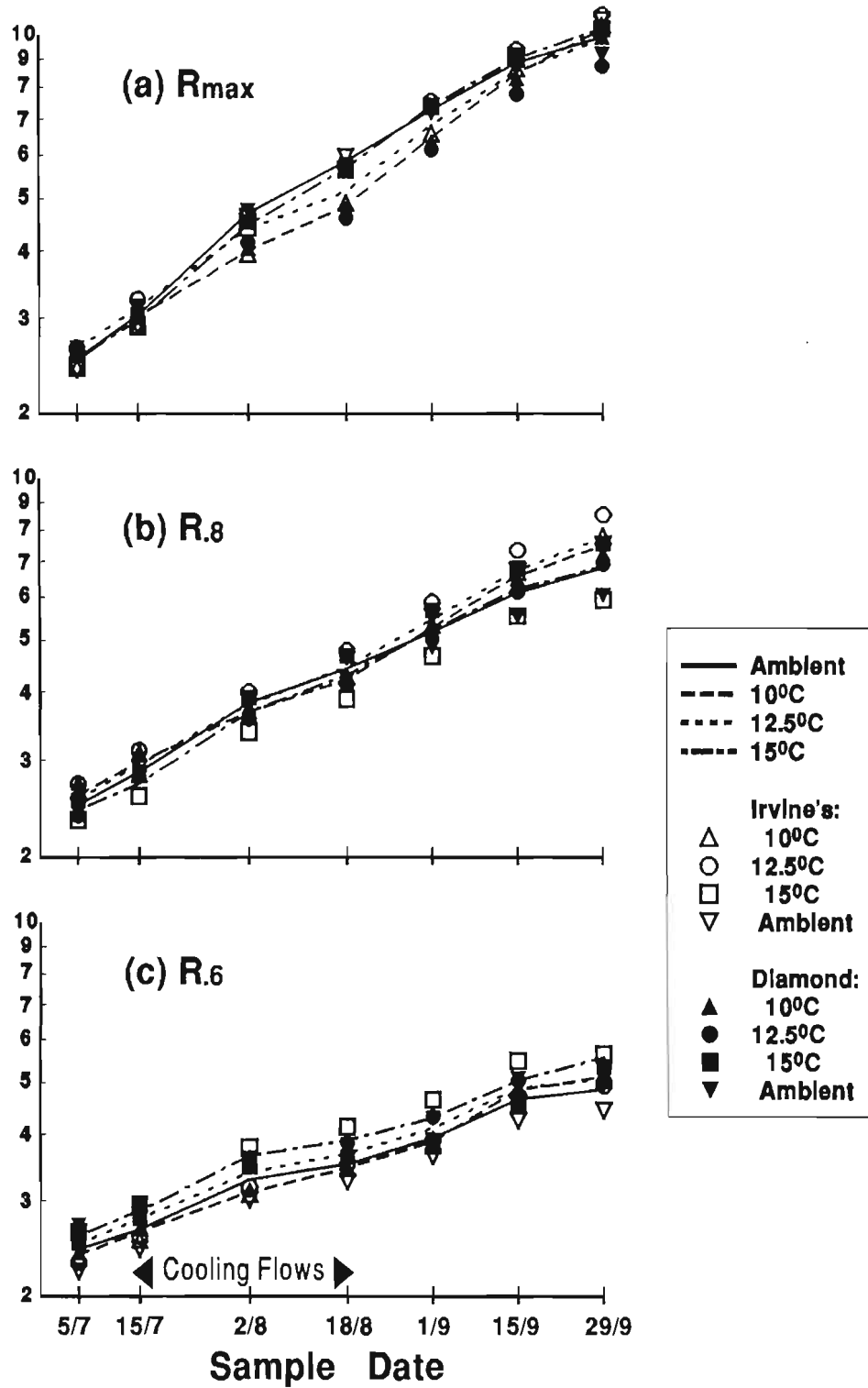


Figure 2 a, b and c. Weight of Nechako chinook fry for comparison at three ration levels, all three plots are to the same scale. Each line is an average of data from Irvine's Lodge and Diamond Island at each temperature.

TABLE 1 EXPERIMENTAL DESIGN (Numbers designate tank identity)

<u>Temperature</u> <u>Ration</u>	source: Irvine's Lodge			source: Diamond Island		
	<u>R_{max}</u>	<u>R_{.6}</u>	<u>R_{.8}</u>	<u>R_{max}</u>	<u>R_{.6}</u>	<u>R_{.8}</u>
<u>Ambient</u>	405	403	506	302	304	401
<u>10°C</u>	305	502	408	402	505	410
<u>12.5°C</u>	301	508	507	504	509	503
<u>15°C</u>	406	407	303	409	501	404

TABLE 2 MEAN OF DAILY TEMPERATURE BY SAMPLE PERIOD (for sample period dates, see Figure 1)

Temp	Ratn	Gp	Period 1	2	3	4	5	6
Ambt	Rmax	Irv	16.6	17.5	18.8	18.1	15.5	13.4
		Diam	16.8	17.6	18.9	18.1	15.5	13.6
	R.6	Irv	16.5	17.3	18.8	17.9	15.5	13.2
		Diam	16.5	17.5	18.9	18.1	15.5	13.4
	R.8	Irv	16.5	17.4	18.8	18.2	15.5	13.5
		Diam	16.6	17.2	18.2	17.4	15.4	13.4
10.0°C	Rmax	Irv	16.7	11.7	10.3	16.6	15.4	13.4
		Diam	16.6	11.7	10.2	16.5	15.5	13.3
	R.6	Irv	16.7	11.7	10.3	16.7	15.8	13.4
		Diam	16.6	11.5	10.3	16.6	15.5	13.3
	R.8	Irv	16.7	11.8	10.2	16.6	15.7	13.4
		Diam	16.6	11.6	10.1	16.5	15.4	13.3
12.5°C	Rmax	Irv	16.7	13.7	12.6	17.2	15.4	13.4
		Diam	16.8	14.0	12.6	17.2	15.6	13.5
	R.6	Irv	16.7	13.6	12.6	17.2	15.4	13.4
		Diam	16.6	13.6	12.4	17.2	15.4	13.3
	R.8	Irv	16.6	13.5	12.5	17.1	15.4	13.4
		Diam	16.7	13.6	12.4	17.1	15.5	13.3
15.0°C	Rmax	Irv	16.4	15.6	15.0	17.6	15.3	13.3
		Diam	16.6	15.6	15.1	17.5	15.4	13.4
	R.6	Irv	16.6	15.6	15.1	17.6	15.4	13.4
		Diam	16.8	15.7	15.1	17.6	15.4	13.4
	R.8	Irv	16.7	15.7	15.2	17.6	15.4	13.4
		Diam	16.7	15.5	15.0	17.5	15.4	13.3

TABLE 3 MEAN WET WEIGHT (g) OF NECHAKO CHINOOK FRY BY SAMPLE

Temp	Rat ⁿ	Gp	Stat	4 Jul	15 Jul	2 Aug	18 Aug	1 Sep	15 Sep	29 Sep
Amb ^c	R _{max}	Irv	n	29	29	28	28	28	28	28
			mean	2.4	2.9	4.6	6.0	7.4	9.1	10.7
			se	0.1	0.1	0.2	0.2	0.3	0.4	0.5
		Diam	n	30	30	30	30	30	30	30
			mean	2.6	3.2	4.7	5.7	7.2	8.6	9.2
			se	0.1	0.2	0.2	0.3	0.4	0.4	0.6
		Irv	n	31	31	30	30	28	28	28
			mean	2.2	2.4	3.0	3.2	3.6	4.2	4.4
			se	0.1	0.1	0.1	0.2	0.2	0.2	0.2
	R ₆	Diam	n	27	27	27	27	27	27	27
			mean	2.7	2.9	3.6	3.8	4.3	5.1	5.3
			se	0.1	0.1	0.1	0.2	0.2	0.2	0.2
		Irv	n	27	27	27	26	26	26	26
			mean	2.5	2.9	3.9	4.7	5.5	6.7	7.5
			se	0.1	0.1	0.2	0.2	0.3	0.3	0.4
		Diam	n	29	29	28	28	28	26	25
			mean	2.5	2.8	3.8	4.2	4.8	5.5	6.0
			se	0.1	0.1	0.2	0.2	0.2	0.3	0.3
10°C	R _{max}	Irv	n	29	29	28	28	28	28	28
			mean	2.4	2.9	3.9	4.9	6.6	8.7	10.4
			se	0.1	0.1	0.2	0.2	0.3	0.3	0.4
		Diam	n	30	30	30	30	30	30	30
			mean	2.5	3.1	4.0	4.8	6.4	8.3	10.0
			se	0.1	0.1	0.2	0.2	0.3	0.3	0.4
		Irv	n	28	28	28	28	28	27	26
			mean	2.3	2.6	3.1	3.4	3.8	4.8	5.2
			se	0.1	0.1	0.1	0.2	0.2	0.2	0.3
	R ₆	Diam	n	29	29	29	29	29	29	29
			mean	2.4	2.7	3.1	3.5	3.9	4.8	5.0
			se	0.1	0.1	0.1	0.2	0.2	0.2	0.3
		Irv	n	28	28	27	27	27	27	27
			mean	2.4	2.8	3.6	4.3	5.3	6.7	7.8
			se	0.1	0.1	0.1	0.2	0.2	0.3	0.3
		Diam	n	28	28	28	28	28	28	28
			mean	2.7	3.1	3.7	4.2	5.2	6.5	7.2
			se	0.1	0.1	0.1	0.2	0.2	0.3	0.4

12.5°C	R_{max}	Irv	n	27	27	26	26	26	26	26
			mean	2.6	3.2	4.6	5.7	7.5	9.4	10.9
			se	0.1	0.1	0.2	0.2	0.3	0.4	0.5
		Diam	n	28	28	28	28	28	27	27
			mean	2.6	3.0	4.1	4.6	6.2	7.8	8.7
			se	0.1	0.1	0.2	0.2	0.3	0.3	0.4
	R_6	Irv	n	29	29	29	29	29	29	29
			mean	2.3	2.6	3.2	3.5	3.9	4.7	4.9
			se	0.1	0.1	0.1	0.1	0.2	0.2	0.2
		Diam	n	29	29	29	29	29	29	26
			mean	2.6	3.0	3.6	3.8	4.3	5.0	5.3
			se	0.1	0.1	0.2	0.2	0.2	0.3	0.4
	R_8	Irv	n	30	30	30	29	29	29	29
			mean	2.7	3.1	4.0	4.8	5.9	7.3	8.5
			se	0.1	0.1	0.2	0.2	0.2	0.2	0.3
		Diam	n	29	29	29	29	29	29	27
			mean	2.4	2.8	3.6	4.1	5.0	6.1	6.9
			se	0.1	0.1	0.2	0.2	0.3	0.3	0.4
15.0°C	R_{max}	Irv	n	29	30	29	29	29	29	29
			mean	2.4	2.9	4.4	5.6	7.4	9.0	10.2
			se	0.1	0.1	0.2	0.3	0.3	0.3	0.4
		Diam	n	29	29	29	29	29	29	29
			mean	2.6	3.0	4.5	5.7	7.4	9.0	10.2
			se	0.1	0.2	0.2	0.3	0.4	0.4	0.5
	R_6	Irv	n	25	27	26	26	26	26	26
			mean	2.6	2.9	3.8	4.1	4.6	5.5	5.6
			se	0.1	0.1	0.2	0.2	0.2	0.3	0.3
		Diam	n	31	28	28	27	25	23	13
			mean	2.5	2.8	3.5	3.7	3.9	4.5	5.3
			se	0.1	0.1	0.2	0.2	0.2	0.2	0.4
	R_8	Irv	n	29	29	25	25	25	25	23
			mean	2.3	2.6	3.4	3.9	4.7	5.5	5.9
			se	0.1	0.1	0.2	0.2	0.2	0.3	0.4
		Diam	n	30	30	29	29	29	29	29
			mean	2.5	2.8	3.9	4.7	5.7	6.8	7.6
			se	0.1	0.1	0.2	0.2	0.2	0.3	0.4

TABLE 4 MEAN LENGTH (cm) OF NECHAKO CHINOOK FRY BY SAMPLE

Temp	Rat ⁿ	Gp	Stat	15 Jul	2 Aug	18 Aug	1 Sep	15 Sep	29 Sep
Amb ^c	R _{max}	Irv	n	23	28	28	28	28	28
			mean	6.4	7.3	7.9	8.4	9.1	9.6
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	30	30	30	30	30	30
			mean	6.5	7.3	7.8	8.3	8.8	9.2
			se	0.1	0.1	0.1	0.1	0.1	0.2
	R _{.6}	Irv	n	31	30	30	28	28	28
			mean	6.1	6.4	6.6	6.8	7.1	7.3
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	27	27	27	27	27	27
			mean	6.4	6.8	7.0	7.1	7.4	7.7
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R _{.8}	Irv	n	27	27	26	26	26	26
			mean	6.3	6.9	7.3	7.7	8.1	8.6
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	29	28	28	28	26	25
			mean	6.3	6.9	7.1	7.4	7.7	8.0
			se	0.1	0.1	0.1	0.1	0.1	0.1
10.0°C	R _{max}	Irv	n	29	28	28	28	28	28
			mean	6.4	7.0	7.6	8.2	8.8	9.5
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	30	30	30	30	30	30
			mean	6.5	7.1	7.5	8.1	8.8	9.4
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R _{.6}	Irv	n	28	28	28	28	27	26
			mean	6.2	6.5	6.8	7.0	7.3	7.6
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	29	29	29	29	29	29
			mean	6.3	6.6	6.8	7.0	7.3	7.6
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R _{.8}	Irv	n	28	27	27	27	27	27
			mean	6.3	6.8	7.3	7.6	8.2	8.7
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	28	28	28	28	28	28
			mean	6.5	6.9	7.3	7.7	8.1	8.5
			se	0.1	0.1	0.1	0.1	0.1	0.1

12.5°C	R_{\max}	Irv	n	27	26	26	26	26	26
			mean	6.4	7.3	7.9	8.5	9.0	9.6
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	28	28	28	28	27	27
			mean	6.5	7.1	7.5	8.0	8.6	9.0
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R_6	Irv	n	29	29	29	29	29	29
			mean	6.1	6.5	6.8	7.0	7.2	7.5
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	29	29	29	29	29	26
			mean	6.4	6.8	7.1	7.2	7.5	7.7
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R_8	Irv	n	30	29	29	29	29	29
			mean	6.5	7.0	7.5	7.9	8.4	8.9
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	29	29	29	29	29	27
			mean	6.3	6.8	7.2	7.5	7.9	8.3
			se	0.1	0.1	0.1	0.1	0.1	0.1
15.0°C	R_{\max}	Irv	n	30	29	29	29	29	29
			mean	6.4	7.2	7.8	8.4	9.0	9.5
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	29	29	29	29	29	29
			mean	6.5	7.3	7.9	8.5	9.0	9.5
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R_6	Irv	n	27	26	26	26	26	26
			mean	6.4	6.9	7.1	7.3	7.6	7.9
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	30	28	27	25	23	13
			mean	6.3	6.7	6.9	7.0	7.2	7.7
			se	0.1	0.1	0.1	0.1	0.1	0.1
	R_8	Irv	n	29	25	25	25	25	23
			mean	6.2	6.7	7.0	7.3	7.6	8.0
			se	0.1	0.1	0.1	0.1	0.1	0.1
		Diam	n	30	29	29	29	29	29
			mean	6.3	6.9	7.4	7.8	8.2	8.6
			se	0.1	0.1	0.1	0.1	0.1	0.1

TABLE 5 MEAN CONDITION FACTOR BY SAMPLE PERIOD, $100 \cdot (W \cdot L^{-3})$

Temp	Rat ⁿ	Gp	Stat	15 Jul	2 Aug	18 Aug	1 Sept	15 Sep	29 Sep
Amb ^c	R _{max}	Irv	n	23	28	28	28	28	28
			mean	1.110	1.157	1.186	1.218	1.215	1.173
			se	0.012	0.008	0.009	0.010	0.010	0.010
		Diam	n	30	30	30	30	30	30
			mean	1.128	1.172	1.185	1.207	1.222	1.130
			se	0.012	0.010	0.012	0.010	0.010	0.014
	R ₆	Irv	n	31	30	30	28	28	28
			mean	1.049	1.103	1.103	1.140	1.182	1.112
			se	0.015	0.018	0.015	0.012	0.011	0.011
		Diam	n	27	27	27	27	27	27
			mean	1.082	1.139	1.116	1.161	1.225	1.127
			se	0.012	0.012	0.012	0.010	0.011	0.011
	R ₈	Irv	n	27	27	26	26	26	26
			mean	1.117	1.143	1.171	1.194	1.228	1.169
			se	0.017	0.014	0.011	0.013	0.013	0.011
		Diam	n	29	28	28	28	26	25
			mean	1.121	1.147	1.137	1.186	1.190	1.165
			se	0.014	0.009	0.009	0.010	0.009	0.009
10.0°C	R _{max}	Irv	n	29	28	28	28	28	28
			mean	1.092	1.121	1.102	1.181	1.231	1.192
			se	0.014	0.012	0.013	0.014	0.010	0.010
		Diam	n	30	30	30	30	30	30
			mean	1.136	1.118	1.091	1.162	1.200	1.197
			se	0.011	0.010	0.011	0.012	0.009	0.012
	R ₆	Irv	n	28	28	28	28	27	26
			mean	1.048	1.069	1.065	1.084	1.218	1.139
			se	0.016	0.013	0.011	0.014	0.015	0.015
		Diam	n	29	29	29	29	29	29
			mean	1.065	1.078	1.061	1.103	1.223	1.132
			se	0.012	0.012	0.009	0.010	0.015	0.015
	R ₈	Irv	n	28	27	27	27	27	27
			mean	1.134	1.119	1.093	1.191	1.211	1.177
			se	0.019	0.009	0.011	0.015	0.011	0.013
		Diam	n	28	28	28	28	28	28
			mean	1.103	1.108	1.063	1.143	1.208	1.142
			se	0.012	0.010	0.013	0.007	0.010	0.010

12.5°C	R_{\max}	Irv	n	27	26	26	26	26	26
			mean	1.193	1.164	1.160	1.214	1.242	1.213
			se	0.017	0.011	0.011	0.013	0.014	0.014
		Diam	n	28	28	28	28	27	27
			mean	1.085	1.120	1.076	1.168	1.198	1.163
			se	0.014	0.009	0.009	0.015	0.012	0.012
	$R_{.6}$	Irv	n	29	29	29	29	29	29
			mean	1.096	1.120	1.098	1.123	1.235	1.163
			se	0.020	0.009	0.009	0.010	0.011	0.011
		Diam	n	29	29	29	29	29	26
			mean	1.092	1.125	1.062	1.120	1.176	1.105
			se	0.013	0.013	0.011	0.012	0.014	0.021
	$R_{.8}$	Irv	n	30	29	29	29	29	29
			mean	1.128	1.135	1.116	1.166	1.221	1.197
			se	0.018	0.017	0.011	0.011	0.012	0.011
		Diam	n	29	29	29	29	29	27
			mean	1.082	1.116	1.083	1.139	1.219	1.190
			se	0.012	0.010	0.011	0.011	0.015	0.011
15.0°C	R_{\max}	Irv	n	30	29	29	29	29	29
			mean	1.103	1.152	1.147	1.217	1.229	1.188
			se	0.017	0.011	0.009	0.009	0.009	0.011
		Diam	n	29	29	29	29	29	29
			mean	1.104	1.117	1.139	1.182	1.199	1.169
			se	0.013	0.010	0.010	0.008	0.009	0.010
	$R_{.6}$	Irv	n	27	26	26	26	26	26
			mean	1.124	1.132	1.123	1.151	1.211	1.130
			se	0.017	0.009	0.010	0.011	0.018	0.014
		Diam	n	28	28	27	25	23	13
			mean	1.104	1.146	1.097	1.124	1.179	1.151
			se	0.012	0.010	0.011	0.012	0.017	0.018
	$R_{.8}$	Irv	n	29	25	25	25	25	23
			mean	1.074	1.104	1.108	1.165	1.222	1.137
			se	0.017	0.014	0.011	0.014	0.021	0.019
		Diam	n	30	29	29	29	29	29
			mean	1.097	1.147	1.144	1.187	1.232	1.162
			se	0.016	0.010	0.011	0.011	0.009	0.010

TABLE 6 SPECIFIC GROWTH BY SAMPLE PERIOD, $100 \cdot (\ln W_n - \ln W_{n-1}) \cdot \text{days}^{-1}$

Temp	Ratn	Gp	Stat	Period	1	2	3	4	5	6
Ambt	Rmax	Irv	n	29	28	28	28	28	28	28
			mean	1.89	2.52	1.58	1.55	1.52	1.09	
			se	0.11	0.07	0.06	0.07	0.04	0.04	
		Diam	n	30	30	30	30	30	30	30
			mean	1.78	2.29	1.13	1.62	1.35	0.31	
			se	0.12	0.08	0.08	0.07	0.08	0.11	
		R.6	Irv	n	31	30	30	28	28	28
			mean	0.89	1.08	0.43	0.72	1.12	0.32	
			se	0.12	0.09	0.08	0.06	0.07	0.06	
			Diam	n	27	27	27	27	27	27
			mean	0.80	1.15	0.39	0.82	1.21	0.28	
			se	0.08	0.07	0.05	0.06	0.06	0.07	
	R.8	Irv	n	27	27	26	26	26	26	26
			mean	1.28	1.59	1.05	1.22	1.41	0.78	
			se	0.12	0.10	0.06	0.05	0.07	0.06	
		Diam	n	29	28	28	28	26	25	
			mean	1.34	1.61	0.63	1.01	0.95	0.63	
			se	0.10	0.08	0.08	0.07	0.09	0.08	
10.0	Rmax	Irv	n	29	28	28	28	28	28	28
			mean	1.71	1.72	1.35	2.11	1.98	1.31	
			se	0.12	0.06	0.05	0.08	0.05	0.05	
		Diam	n	30	30	30	30	30	29	
			mean	2.14	1.42	1.03	2.07	1.91	1.30	
			se	0.10	0.07	0.07	0.07	0.06	0.07	
		R.6	Irv	n	26	26	28	28	27	26
			mean	0.83	0.92	0.66	0.70	1.60	0.51	
			se	0.16	0.08	0.06	0.12	0.07	0.10	
		Diam	n	29	29	29	29	29	29	29
			mean	0.93	0.91	0.62	0.91	1.43	0.23	
			se	0.09	0.08	0.07	0.06	0.09	0.11	
	R.8	Irv	n	28	27	27	27	27	27	27
			mean	1.46	1.25	1.05	1.56	1.65	1.10	
			se	0.13	0.04	0.05	0.07	0.06	0.06	
		Diam	n	28	28	28	28	28	28	28
			mean	1.32	1.02	0.60	1.63	1.57	0.69	
			se	0.09	0.07	0.09	0.08	0.07	0.10	

12.5	Rmax	Irv	n	27	26	26	26	26	26
			mean	2.07	1.89	1.31	1.92	1.53	1.07
			se	0.14	0.09	0.05	0.11	0.10	0.06
		Diam	n	27	27	28	28	27	27
			mean	1.32	1.67	0.62	2.02	1.44	0.81
			se	0.18	0.09	0.08	0.13	0.09	0.10
		R.6	Irv	n	29	29	29	29	29
			mean	0.85	1.19	0.62	0.72	1.38	0.30
			se	0.09	0.04	0.05	0.05	0.07	0.05
	R.6	Diam	n	29	29	29	29	29	26
			mean	1.04	1.08	0.41	0.81	1.08	0.31
			se	0.07	0.06	0.06	0.06	0.08	0.13
		R.8	Irv	n	30	30	29	29	29
			mean	1.21	1.34	0.97	1.51	1.61	1.06
			se	0.14	0.11	0.06	0.08	0.07	0.06
		Diam	n	27	27	29	29	29	27
			mean	1.44	1.40	0.87	1.41	1.42	0.94
			se	0.16	0.06	0.05	0.06	0.10	0.21
15.0	Rmax	Irv	n	29	29	29	29	29	29
			mean	1.58	2.44	1.54	1.96	1.45	0.89
			se	0.10	0.07	0.07	0.08	0.06	0.05
		Diam	n	29	29	29	29	29	29
			mean	1.67	2.16	1.46	1.86	1.48	0.85
			se	0.15	0.07	0.08	0.07	0.06	0.08
		R.6	Irv	n	25	26	26	26	26
			mean	1.19	1.26	0.54	0.79	1.16	0.19
			se	0.15	0.05	0.05	0.06	0.09	0.07
	R.6	Diam	n	28	26	27	25	23	13
			mean	0.98	1.07	0.18	0.39	0.76	0.12
			se	0.14	0.06	0.08	0.08	0.11	0.26
		R.8	Irv	n	29	25	25	25	23
			mean	0.97	1.44	0.88	1.31	1.21	0.42
			se	0.15	0.07	0.06	0.06	0.09	0.11
		Diam	n	30	29	29	29	29	29
			mean	1.19	1.73	1.09	1.42	1.29	0.72
			se	0.15	0.05	0.07	0.10	0.11	0.08

TABLE 7 MORTALITY RECORD FOR NECHAKO CHINOOK, CHRONOLOGICAL ORDER

Tank ID	Tag	Date	Wt (g)	Comment recorded
502	E46324B	5/7	2.1	tagging mortality
503	E353875	4/7	1.7	tagging mortality
508	F140C17	8/7	1.4	tail rot
501	F087B33	10/7	2.1	
303	E472F6A	15/7	3.1	SD handling mortality
303	E47153F	15/7	2.3	SD handling mortality
303	E47147D	15/7	3.1	SD handling mortality
305	E473F2D	15/7	2.3	SD handling mortality
407	F10560B	22/7	1.0	thin
501	E352F0A	21/7	2.3	
303	E351058	30/7	1.6	
501	E462278	29/7	1.4	
404	D18067C	31/7	1.6	moribund, sacrificed
408	E2D0157	2/8	1.3	runt, sacrificed
403	E473800	2/8	1.9	SD handling mortality
405	E463615	2/8	2.4	SD handling mortality
406	E141041	2/8	6.6	SD handling mortality
301	E1E6D77	2/8	0.9	SD sacrifice
501	F141243	17/8	2.4	moribund, sacrificed
506	D17096C	18/8	1.5	dead before sampling
507	F140B61	18/8	1.1	SD sacrifice
403	D172A38	18/8	3.7	SD handling mortality
501	E2D1063	26/8	3.7	
501	E463947	28/8	2.7	
403	E58426C	29/8	1.6	
502	E0E1F16	7/9	no wt	ragged runt
501	E462D64	10/9	2.97	ragged tail
401	E1E3005	12/9	5.46	moribund, to Fish Health
continued next page:				

Tank ID	Tag	Date	Wt (g)	Comment recorded
501	E354842	12/9	2.07	moribund, ragged
401	E462B0D	14/9	5.46	moribund, to Fish Health
504	E462559	15/9	1.1	dead before sampling
503	F447C31	16/9	5.44	moribund, sacrificed
401	F14037D	19/9	4.87	moribund, sacrificed
501	F3F4E51	19/9	4.53	moribund, sacrificed
503	E2C461D	20/9	9.96	as above, a fat fish
501	E464B68	22/9	3.26	ragged
303	F0C5465	23/9	7.54	dry, under lid. FL = 8.2cm
501	E462742	23/9	3.35	moribund, to Histology
501	E461E0D	25/9	3.5	
501	F105B67	25/9	4.2	
501	E6D1713	26/9	3.8	
501	E20217C	26/9	3.2	
509	E0E1979	26/9	5.0	
509	E6D142B	26/9	4.4	
303	F451560	26/9	4.7	
501	E46261C	27/9	3.70	ragged
501	E462F1D	27/9	4.59	moribund, to Histology

Notes

SD indicates Sampling Day.

Mortalities are listed in chronological order. For identity of treatment, see experimental design (Table 1).

TABLE 8 TOTAL FISH WEIGHT (W1-W7). **BOLD DATA** WERE ADJUSTED FOR MORTALITY TO GIVE EQUAL n

Tank	Temp	Rat ⁿ	Gp	W1	W2in	W2out	W3in	W3out	W4in	W4out	W5in	W5out	W6in	W6out	Wt7
405	Ambt	R _{max}	Irv	69.6	84.2	84.2	132.0	129.6	166.8	166.8	206.9	206.9	255.8	255.8	298.7
302			Diam	78.9	94.6	94.6	142.5	142.5	172.4	172.4	215.2	215.2	259.1	259.1	275.2
403		R ₆	Irv	68.6	75.2	75.2	92.3	90.4	97.4	93.7	101.5	101.5	118.7	118.7	123.9
304			Diam	72.5	78.5	78.5	96.8	96.8	103.1	103.1	115.5	115.5	136.9	136.9	142.6
506		R ₈	Irv	69.5	78.2	78.2	104.4	104.4	122.4	120.9	143.4	143.4	174.9	174.9	195.6
401			Diam	71.6	81.7	81.7	109.1	105.9	117.5	117.5	135.4	135.4	153.8	138.3	156.0
305	10°C	R _{max}	Irv	70.1	83.5	81.2	110.4	110.4	137.3	137.3	184.2	184.2	242.4	242.4	291.3
402			Diam	76.4	94.2	94.2	121.1	121.1	143.3	143.3	191.2	191.2	248.9	248.9	300.2
502		R ₆	Irv	65.4	72.2	72.2	86.1	86.1	96.2	96.2	106.7	106.7	130.7	130.7	135.0
505			Diam	69.6	77.2	77.2	91.0	91.0	100.5	100.5	114.3	114.3	140.2	140.2	146.0
408		R ₈	Irv	68.2	79.3	79.3	98.7	97.4	115.4	115.4	143.5	143.5	180.2	180.2	210.4
410			Diam	76.5	87.3	87.3	104.9	104.9	116.3	116.3	145.5	145.5	181.7	181.7	202.1
301	12.5°	R _{max}	Irv	70.9	87.4	87.4	121.7	120.8	148.9	148.9	195.7	195.7	243.4	243.4	283.4
504			Diam	73.1	81.4	81.4	115.9	115.9	128.5	128.5	172.3	172.3	210.8	209.7	236.0
508		R ₆	Irv	67.6	74.6	74.6	92.1	92.1	101.7	101.7	112.8	112.8	136.8	136.8	142.6
509			Diam	76.7	85.8	85.8	104.3	104.3	111.5	111.5	125.0	125.0	145.8	145.8	149.0
507		R ₈	Irv	81.3	93.6	93.6	120.1	119.0	138.4	138.4	170.2	170.2	212.8	212.8	247.6
503			Diam	68.6	75.5	75.5	103.6	103.6	119.6	119.6	145.4	145.4	177.7	162.3	186.8
406	15°C	R _{max}	Irv	73.8	86.9	86.9	134.6	128.0	163.8	163.8	214.2	214.2	262.0	262.0	297.2
409			Diam	74.3	88.3	88.3	130.7	130.7	165.1	165.1	213.8	213.8	261.9	261.9	296.6
407		R ₆	Irv	70.3	79.6	78.6	98.3	98.3	107.5	107.5	120.6	120.6	142.4	142.4	146.6
501			Diam	75.0	82.6	77.9	93.6	91.2	96.9	94.5	100.1	93.7	104.5	99.4	69.4
303		R ₈	Irv	67.5	74.9	66.4	86.1	84.5	96.9	96.9	116.4	116.4	138.3	138.3	147.6
404			Diam	75.9	85.4	85.4	115.1	113.5	135.3	135.3	164.5	164.5	196.9	196.9	219.0

Note -in and -out in column heads refer to weight total used in conversion calculations at the same sample time. In is the value ending of one period and out that starting the next.

TABLE 9

FEED CONVERSION, $100 \cdot (\text{grams gained} \cdot \text{grams fed}^{-1})$, AS PERCENT DRY WEIGHT GAINED PER GRAM FED BY SAMPLE PERIOD FOR NECHAKO CHINOOK FRY

Temp	Ratn	Gp	Period	1	2	3	4	5	6
Ambient	Rmax	Irv	16.07	22.11	19.40	21.68	24.62	21.09	
		Diam	15.84	21.31	16.14	21.25	21.07	9.27	
	R.6	Irv	18.20	18.67	10.37	13.01	26.61	9.72	
		Diam	16.54	18.14	8.86	18.77	29.50	9.05	
	R.8	Irv	15.43	19.00	16.65	21.03	27.07	19.15	
		Diam	19.53	18.39*	9.70	17.37	18.04*	15.49*	
10.0°C	Rmax	Irv	14.41	20.33	20.81	22.40	26.57	21.96	
		Diam	17.15	19.71	19.50	23.44	25.62	21.65	
	R.6	Irv	15.78	19.95	21.97	14.84	30.11	5.90	
		Diam	16.93	19.71	19.60	17.87	30.31	7.44	
	R.8	Irv	19.94	20.01	22.08	22.75	26.82	21.29	
		Diam	18.68	17.82	13.86	23.37	28.00	14.99	
12.5°C	Rmax	Irv	17.34	19.22	19.51	22.39	24.01	20.87	
		Diam	10.27	22.88	12.58	23.10	20.94	15.25	
	R.6	Irv	14.05	23.10	19.37	14.79	30.11	9.45	
		Diam	22.43	20.28	13.10	16.56	23.36	4.92*	
	R.8	Irv	22.53	20.50	19.86	21.87	26.70	24.67	
		Diam	13.07	27.36	20.44	21.01	23.98	17.37*	
15°C	Rmax	Irv	13.71*	21.25	20.94	23.05	24.11	18.35	
		Diam	14.55	21.55	19.79	21.98	23.82	18.09	
	R.6	Irv	23.56*	19.32	14.08	17.29	27.84	6.66	
		Diam	16.28*	16.13*	9.28*	11.80*	17.90*	N/A	
	R.8	Irv	13.65	17.53*	14.76	19.68	23.10	10.98*	
		Diam	17.18	20.73	19.27	20.85	24.25	17.01	

Notes

- * best estimates, made for fish losses between samplings.
 N/A excessive fish loss in this period, data not computed.

TABLE 10

DAILY RATION, $100 \cdot (\text{grams fed} \cdot \text{gram fish}^{-1} \cdot \text{day}^{-1})$, AS PERCENT DRY WEIGHT FED PER GRAM FISH PER DAY BY SAMPLE PERIOD FOR NECHAKO CHINOOK FRY

Temp	Ratn	Gp	Period	1	2	3	4	5	6
Ambt	Rmax	Irv	11.87	11.39	8.15	7.11	6.17	5.25	
		Diam	10.43	10.76	7.39	7.47	6.30	4.65	
	R.6	Irv	5.05	6.11	4.50	4.39	4.21	3.15	
		Diam	4.81	6.43	4.45	4.32	4.12	3.21	
	R.8	Irv	6.95	8.48	5.98	5.81	5.25	4.17	
		Diam	6.76	8.71*	6.70	5.84	5.05*	4.04*	
10.0°C	Rmax	Irv	12.16	8.43	6.56	9.40	7.40	5.98	
		Diam	12.23	7.10	5.40	8.82	7.37	6.19	
	R.6	Irv	5.70	4.91	3.16	4.99	4.82	3.92	
		Diam	5.57	4.64	3.17	5.15	4.82	3.89	
	R.8	Irv	7.57	6.09	4.81	6.86	6.08	5.20	
		Diam	7.07	5.73	4.65	6.86	5.68	5.07	
12.5°C	Rmax	Irv	10.99	9.61	6.71	8.74	6.50	5.22	
		Diam	9.52	8.63	5.13	9.10	6.89	5.53	
	R.6	Irv	5.05	5.08	3.20	5.01	4.58	3.14	
		Diam	4.55	5.36	3.18	4.93	4.71	3.15*	
	R.8	Irv	5.69	6.77	4.76	6.77	5.98	4.39	
		Diam	6.67	6.45	4.40	6.65	5.98	4.94*	
15.0°C	Rmax	Irv	11.93*	11.53	7.38	8.34	5.98	4.91	
		Diam	11.88	10.18	7.39	8.42	6.09	4.91	
	R.6	Irv	4.99*	6.45	3.97	4.75	4.27	3.12	
		Diam	5.39*	6.33*	4.08*	4.88*	4.35*	N/A	
	R.8	Irv	7.63	8.26	5.80	6.67	5.34	4.41*	
		Diam	6.87	8.03	5.70	6.71	5.30	4.47	

Notes

* best estimates, made for fish losses between samplings.
 N/A excessive loss in this period, data not computed.

