Aquaculture, 45 (1985) 21—31
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

GROWTH AND DEVELOPMENT OF SEAWATER ADAPTABILITY BY JUVENILE FALL CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) IN RELATION TO TEMPERATURE

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ABSTRACT

Clarke, W.C. and Shelbourn, J.E., 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) in relation to temperature. *Aquaculture*, 45: 21—31.

Fall chinook salmon (*Oncorhynchus tshawytscha*) fry were reared in fresh water and transferred to sea water at intervals in order to determine the optimum conditions for entry into sea water. The three factors in the experiment were temperature in fresh water (7 to 17°C), temperature in sea water (9.5 to 14.5°C) and time of transfer to sea water (April to June). Fry of 1.50 g and larger could survive and grow in sea water. There was a considerable delayed mortality in sea water associated with scale loss in fish which were reared in warm water. The optimum for regulation of plasma sodium concentrations occurred with transfer of 5.6-g fish from 13.8°C fresh water to 10.2°C sea water on 18 May. Maximal growth in sea water relative to that in fresh water occurred with transfer of 6-g fish from 9.7°C fresh water to 14.1°C sea water on 11 June.

INTRODUCTION

Chinook salmon exhibit a variety of juvenile and adult migratory patterns (Reimers, 1973; Healey, 1980, 1982). In coastal rivers of British Columbia, the principal adult chinook migration is the fall run which enters the rivers in September for spawning in October. In some rivers, there are also spring chinook which enter the river in February to May and spawn in late September to October (Carl and Healey, 1984). Three juvenile migratory patterns have been observed. The most numerous is composed of fry which enter the estuary shortly after emergence, rear for up to 6 weeks and enter the ocean at a size of about 4 g or 70 mm fork length (Healey, 1980; Levy and Northcote, 1982). A second downstream migration occurs in June after 3 months in the river, followed by a short estuarine residence before movement offshore (Lister and Walker, 1966; Carl and Healey, 1984). The third and least numerous group consists of yearling migrants which leave the river during May and June and move rapidly through the estuary.

Present hatchery practice involves rearing of fall chinook for 3—4 months

0044-8486/85/$03.30

until release at a weight of approximately 5 g. Seawater challenge tests conducted on hatchery stocks of fall chinook salmon have indicated that seawater adaptability improves with increasing size to about 4—5 g (Clarke and Blackburn, 1978). Photoperiod manipulation during a 3-month laboratory experiment failed to alter growth or development of seawater adaptability in juvenile fall chinook although it did influence the development of coho fry (Clarke et al., 1981).

The present paper describes an experiment conducted in order to determine the influence of temperature in fresh and salt water and time of entry upon the ability of juvenile fall chinook salmon to adapt to sea water.

MATERIALS AND METHODS

Fall chinook salmon eggs were taken at the Big Qualicum River hatchery on Vancouver Island in October and transferred to the Pacific Biological Station for incubation. In late March, groups of 55 fry weighing 0.6 g were placed in 197-liter tanks with water inflow of 5 l/min. The lights were switched on and off by automatic timers without a twilight period. Seasonal changes in daylength were simulated by manual adjustments of the timers to the nearest 15 min. Light intensity at the water surface was 40—60 lux. Oregon Moist pellets were presented in excess of satiation during four 30-min periods daily, using automatic feeders. All fish in each tank were weighed individually at 3-week intervals.

Experimental conditions were arranged in a 3-factor composite factorial design (Alderdice and Thomson, 1974) involving 14 treatment combinations each with 2 replicates plus a center point with 4 replicates. The limits of the factor space were freshwater temperatures of 6.9—17.1°C, seawater temperatures of 9.4—14.6°C and seawater transfers from 14 April to 25 June. Actual daily mean temperatures observed in the tanks are given in Table I. Fish transferred to sea water at a temperature different from their freshwater rearing temperature were allowed to acclimate to the new temperature at the rate of 2°C per day prior to transfer. Transfers were accomplished by switching the incoming water supply to the tanks from fresh to 30‰ sea water.

Seawater adaptability was assessed both by osmoregulatory and growth performance after transfer to sea water. Osmoregulatory performance was determined by measuring plasma sodium concentrations in a sample of 15 fish one day following transfer to sea water (Clarke and Blackburn, 1977; Clarke, 1982). Growth in sea water was assessed following a week of acclimation since preliminary experiments had shown highly variable growth rates immediately after transfer. Fish were weighed 1 week after transfer and again 3 weeks later. This period from the second through the fourth week in sea water was used to calculate growth rates since mortalities in some groups increased at later times, causing increasing variability in growth measurements.

Because growth potential is strongly size dependent, the seawater growth rates were expressed as a ratio to those of fish of the same size in fresh water of the same temperature. A nonlinear quadratic equation relating specific growth rate to weight and temperature in fresh water was used to compute the expected growth rate of fish during the period 2—4 weeks after transfer to sea water; the observed growth rate was then divided by the expected growth rate to obtain a relative growth rate. The plasma sodium and relative seawater growth data were subjected to nonlinear response surface analysis (Bilton et al., 1982; Schnute and McKinnell, 1984) in order to determine the optimum rearing conditions for seawater transfer.

RESULTS

Growth in fresh water

Growth increased with temperature in the range of 7—17°C (Fig. 1). In 3 months the fry grew from an initial weight of 0.6 g to 5 g at 8°C and 16 g at 16°C.

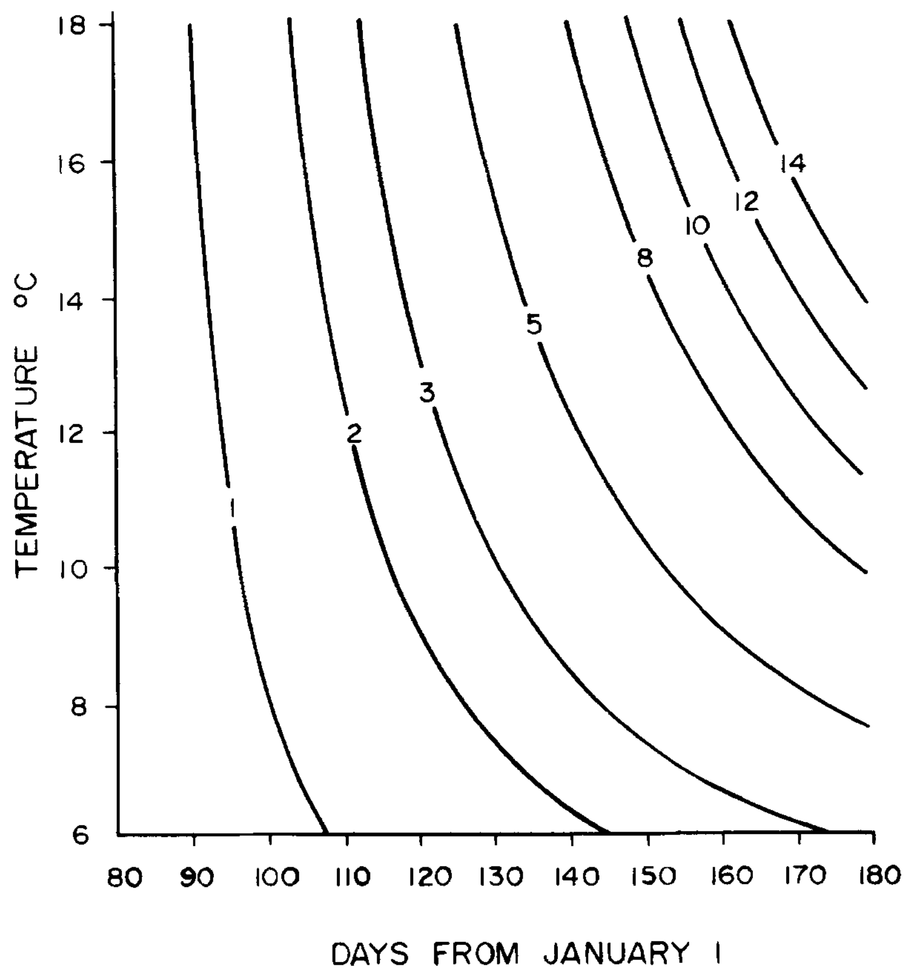

Fig. 1. Response surface contours for weight of juvenile fall chinook in relation to fresh water temperature and time.

Mortality

Mortality in fresh water was less than 5% in all groups except one tank at 16°C which suffered a loss of six fish. There was a noticeable loss of scales in some tanks and this was associated with substantial mortality after transfer to sea water. During the first week after transfer, only four tanks had mortalities; most of the losses began later. Mortality during the first month after transfer to sea water is given in Table I. Descaling in fresh

TABLE I

Mean temperatures, time of transfer, weight at transfer, growth rate in sea water and mortality during the first month in sea water

FW Temp. (°C)	SW Temp. (°C)	Transfer day	Weight at transfer (g)	SW Growth weeks 2—4 (% body wt./day)	Mortality	
					N	%
8.2	10.0	112	1.3	2.69	0	0
8.1	10.1	112	1.4	2.47	0	0
15.8	10.1	112	2.6	1.90	0	0
16.5	10.2	112	2.5	2.31	0	0
8.1	13.8	112	1.3	3.58	1	3
8.1	14.0	112	1.2	3.63	3	7
16.1	13.8	112	2.6	2.31	0	0
16.0	14.0	112	2.5	2.35	19	44
8.1	10.1	168	4.9	2.31	0	0
8.1	10.2	168	4.5	2.36	0	0
16.1	9.9	168	12.6	0.42	8	22
15.9	10.2	168	13.6	0.74	6	19
8.2	14.0	168	4.7	2.99	0	0
8.1	14.0	168	4.4	3.19	0	0
16.2	14.0	168	14.7	1.28	12	40
16.0	14.0	168	12.0	3.20	34	89
7.1	11.8	140	2.3	2.94	0	0
7.2	12.0	140	2.4	3.14	0	0
17.1	11.9	140	7.2	1.57	1	3
17.1	12.2	140	7.6	1.04	3	9
12.0	9.5	140	4.6	2.02	0	0
12.4	9.5	140	5.2	1.82	0	0
12.2	14.4	140	4.8	2.91	0	0
12.1	14.6	140	4.8	2.34	1	3
12.1	12.0	104	1.6	2.81	0	0
12.1	12.0	104	1.5	2.74	2	5
12.0	11.8	176	10.5	1.33	1	3
12.1	11.8	176	11.7	1.53	0	0
12.2	11.9	140	5.1	2.36	0	0
12.1	12.0	140	4.6	2.42	0	0
12.2	12.0	140	4.8	2.35	0	0
12.0	12.0	140	4.5	2.31	0	0

water was particularly severe in groups reared at 16 or 17°C. Some groups reared at 8 or 12°C in fresh water and subsequently transferred to 14°C sea water also exhibited heavy mortality after they reached a weight of approximately 10 g.

Plasma sodium concentrations

The response center for plasma sodium concentration 24 h after transfer to sea water was a minimum at 164.5 meq/l. This occurred after transfer from 13.8°C fresh water to 10.2°C sea water on 18 May (Fig. 2). At this point, the fish weighed 5.6 g. Inspection of the surface reveals that regulation of plasma sodium levels was influenced most by freshwater temperature and time of transfer, while seawater temperature had a lesser effect. Time of transfer had an asymmetric effect; regulation of plasma sodium improved rapidly during late April and early May before the optimum but

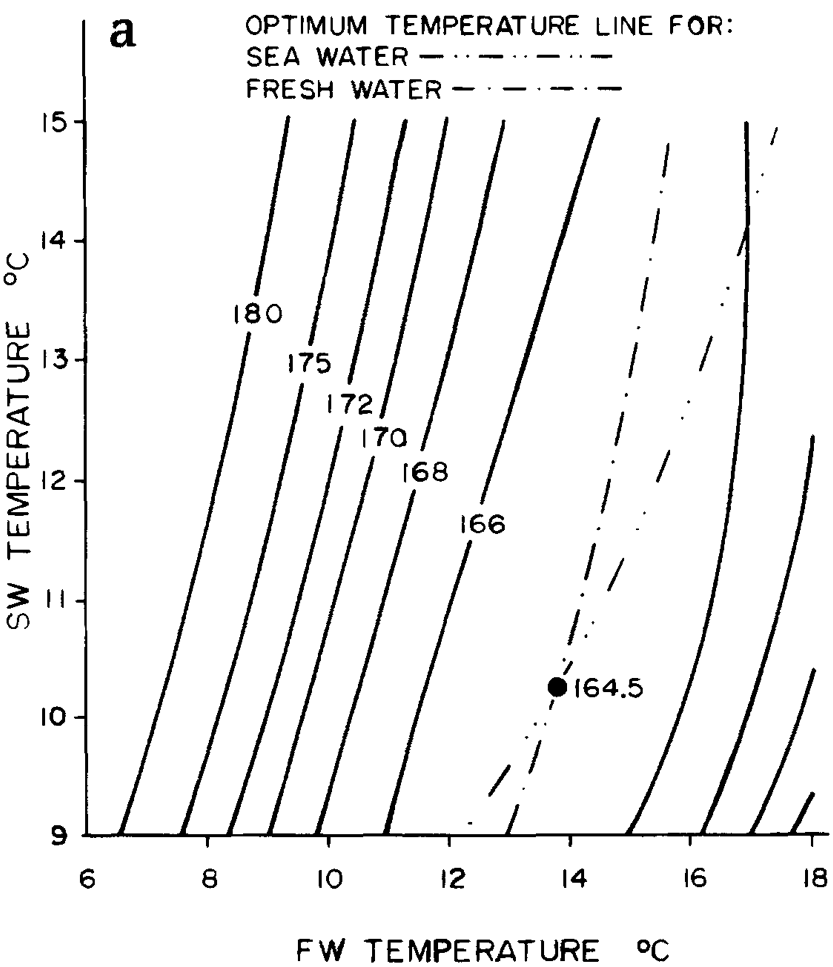

Fig. 2a. Contours on a plane through the response center of plasma sodium concentration 24 h after transfer to sea water, slice at Julian day 138.5.

then remained high well into July. On the other hand, freshwater temperature had a relatively symmetrical effect above and below the optimum. The optimum transfer time ranged from about the first week of May to the first week of July as freshwater temperature declined from 17°C to 9°C (Fig. 2b). Optimum transfer time was influenced much less by seawater temperature, ranging by only about 10 days in May in response to a change from 14°C to 10°C (Fig. 2c).

Growth in sea water

Fish of 1.5 g and larger could survive and grow in sea water. Growth in sea water was equal to or better than that in fresh water for fish larger than 2 g transferred from 8—12°C fresh water. Freshwater temperatures of 7—10°C

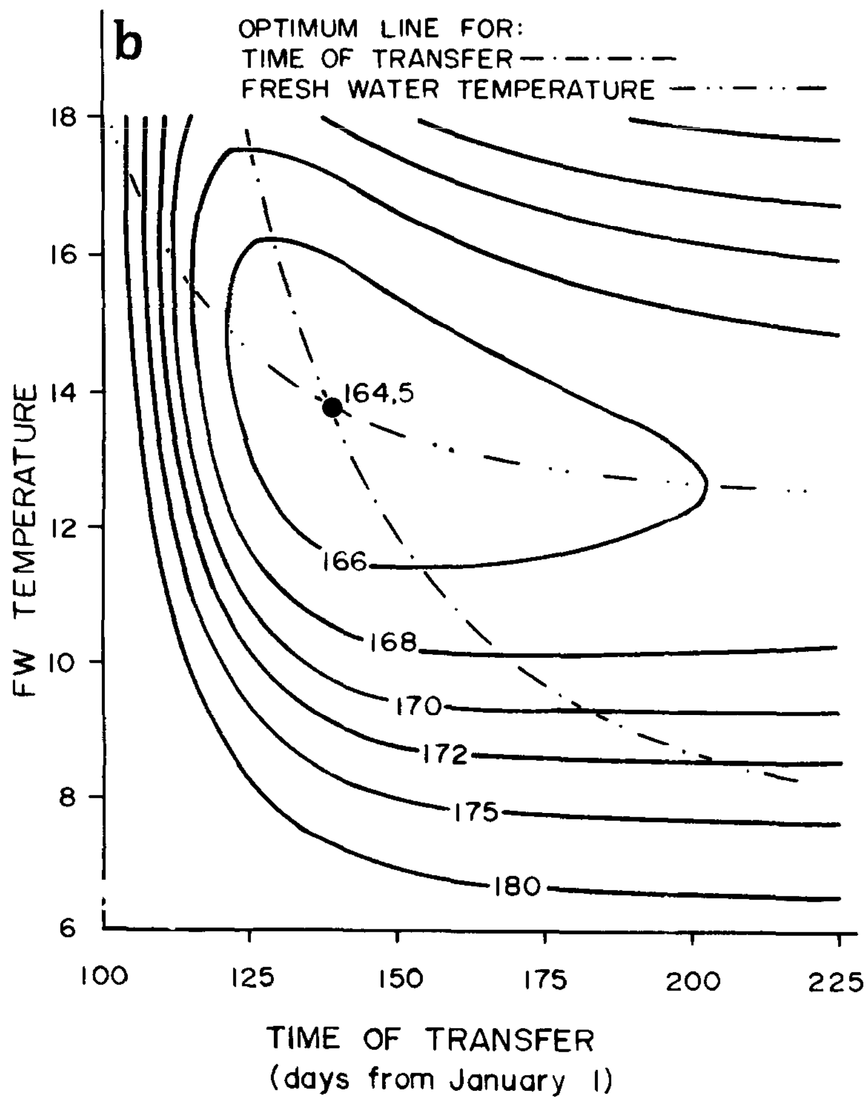

Fig. 2b. Contours on a plane through the response center of plasma sodium concentration 24 h after transfer to sea water, slice at 10.2°C sea water.

produced best growth after transfer to seawater temperatures in the range of 9—12°C (Fig. 3a). Maximal relative growth in sea water was estimated to occur after transfer from 9.7°C fresh water to 14.1°C sea water on 11 June (Fig. 3a,b,c). This point corresponds to a fish weight of 6 g. At the center of the response surface, growth rate was 1.4 times that of fish in fresh water at the same temperature. Freshwater rearing temperature had a considerable influence on optimum time for transfer to sea water, advancing it by 40 days from the end of June at 8°C to mid-May at 17°C (Fig. 3b). This corresponds to fish weights of approximately 5 and 7.5 g, respectively. Optimum transfer time was influenced little by seawater temperatures except near the response center (Fig. 3c). Relative growth declined sharply at seawater temperatures above 14.5°C (Fig. 3a,c).

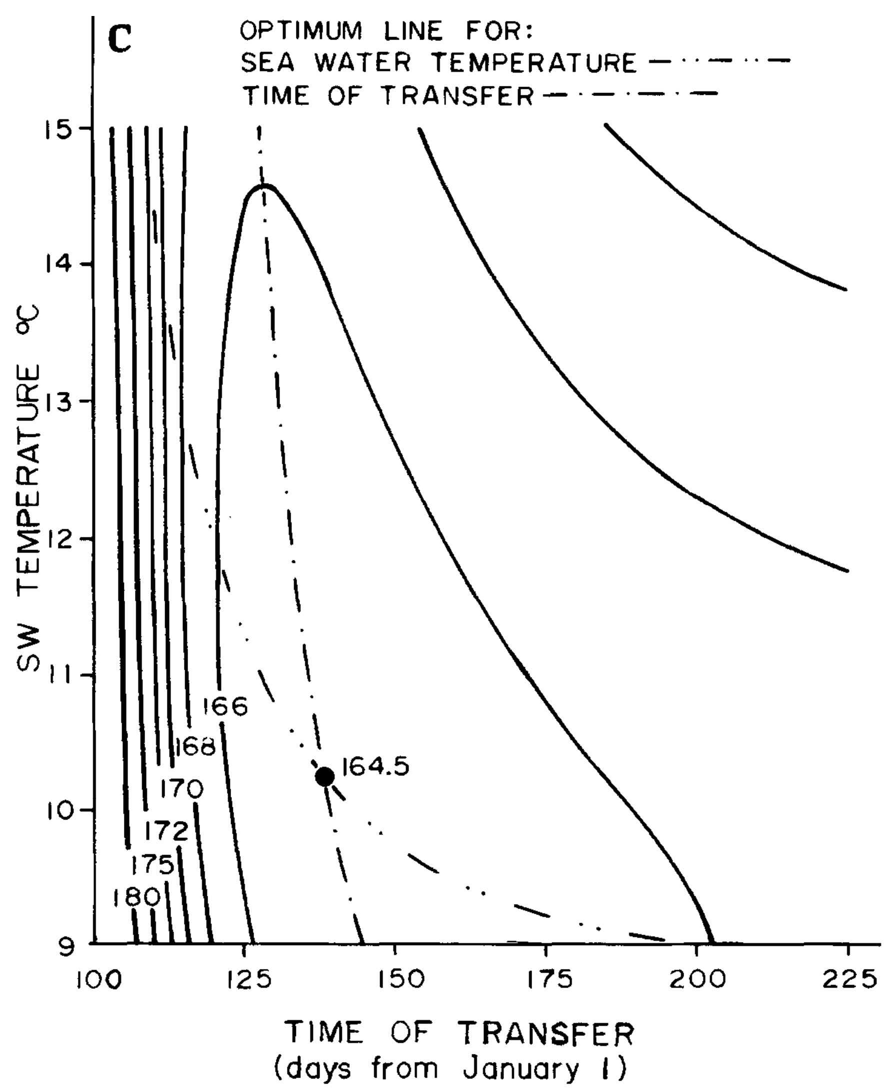

Fig. 2c. Contours on a plane through the response center of plasma sodium concentration 24 h after transfer to sea water, slice at 13.8°C fresh water.

DISCUSSION

The results of the present experiment indicated that freshwater rearing temperature and time of transfer are the most important factors influencing the ability of juvenile fall chinook salmon to regulate plasma sodium concentrations and grow in sea water. The response surface for plasma sodium indicated somewhat different optimum rearing conditions than did the surface for relative growth in sea water. Osmoregulatory preadaptation to sea water was best when fish reared in 10—17.5°C fresh water were transferred to sea water from early May onwards. Relative growth in sea water was greatest when fish reared in 8—14°C fresh water were transferred to 13—14.5°C sea water from early May onwards. However, there was little difference in weight of the fish at the optimum for sodium regulation (5.6 g) and growth (6 g). Seawater adaptability remained high beyond the

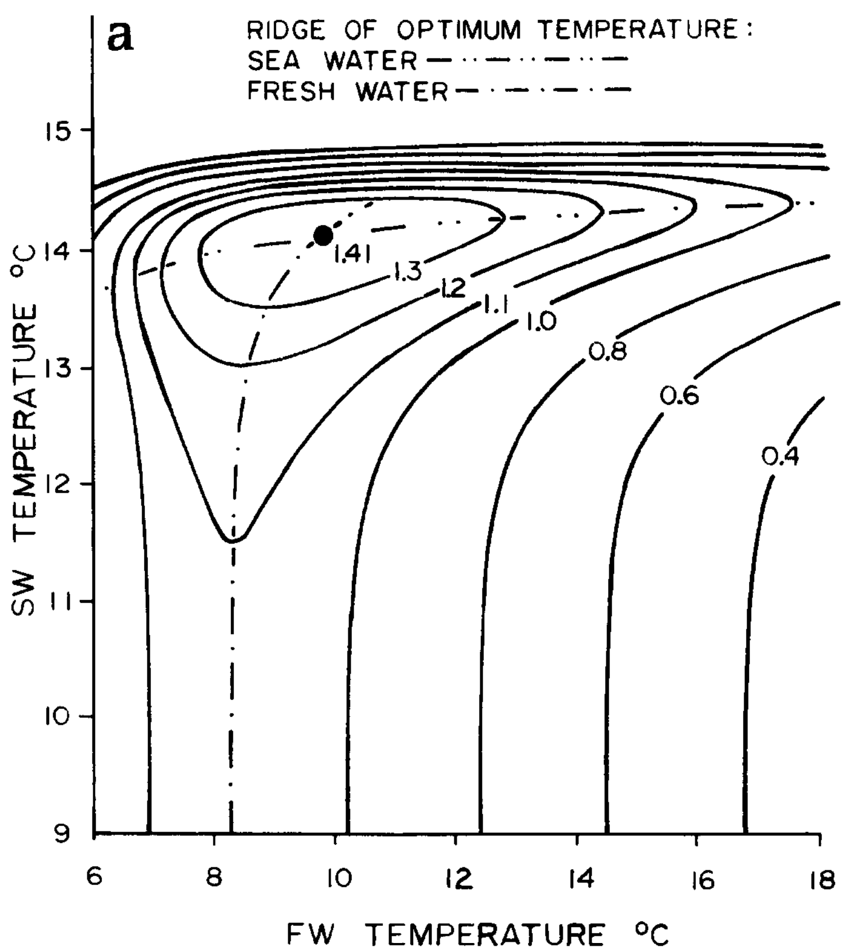

Fig. 3a. Contours on a plane through the response center of relative growth during the second through fourth weeks after transfer to sea water, slice at Julian day 163.9.

optimum transfer time and did not decline appreciably before the end of the experiment.

Earlier seawater challenge tests of juvenile fall chinook in hatcheries have shown that hypoosmoregulatory ability remains high well into July (Clarke and Blackburn, 1978). In this respect, fall chinook differ from accelerated underyearling coho which undergo a rapid decline in seawater adaptability during July (Clarke and Shelbourn, 1982).

Wagner et al. (1969) reported that fall chinook fry could survive abrupt transfer to 30‰ sea water at a weight of 3 g. Kepshire and McNeil (1972) acclimated chinook fry to sea water by stepwise increases in salinity and demonstrated that 1-g fry survived well at 33‰ although growth was retarded in comparison with that at lower salinities.

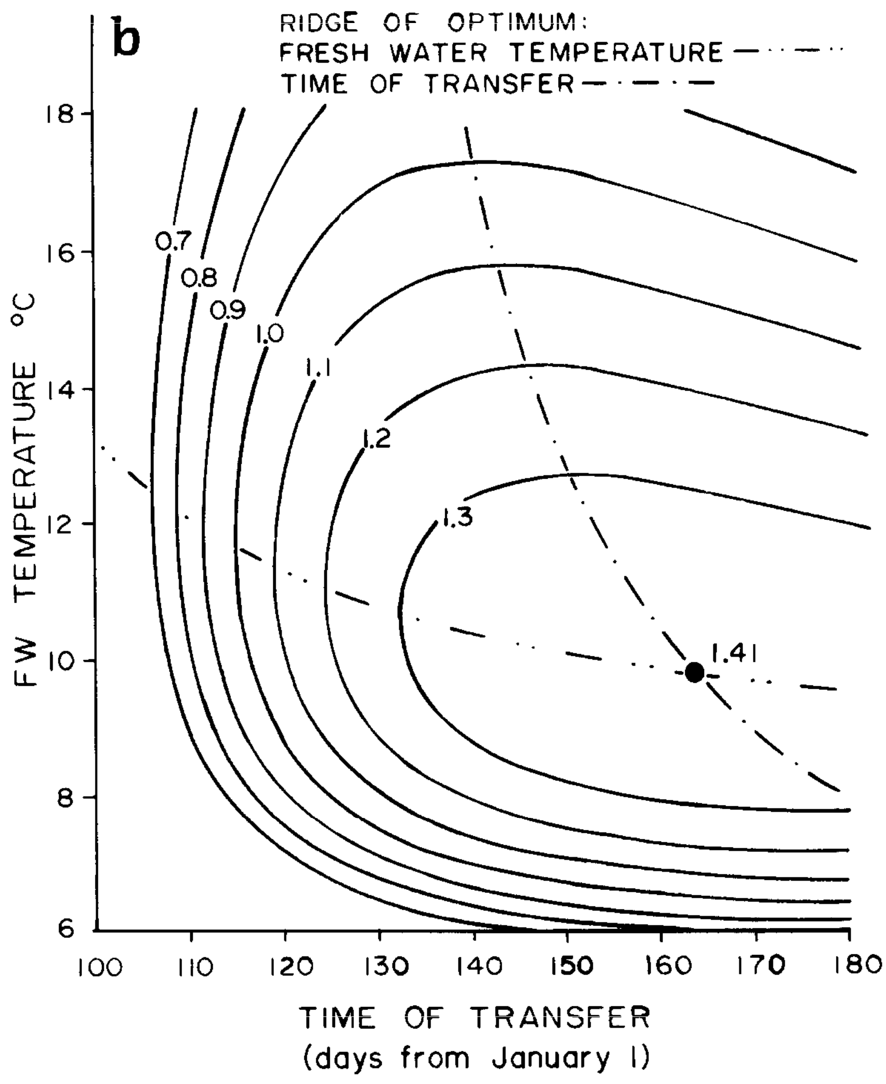

Fig. 3b. Contours on a plane through the response center of relative growth during the second through fourth weeks after transfer to sea water, slice at 14.1°C sea water.

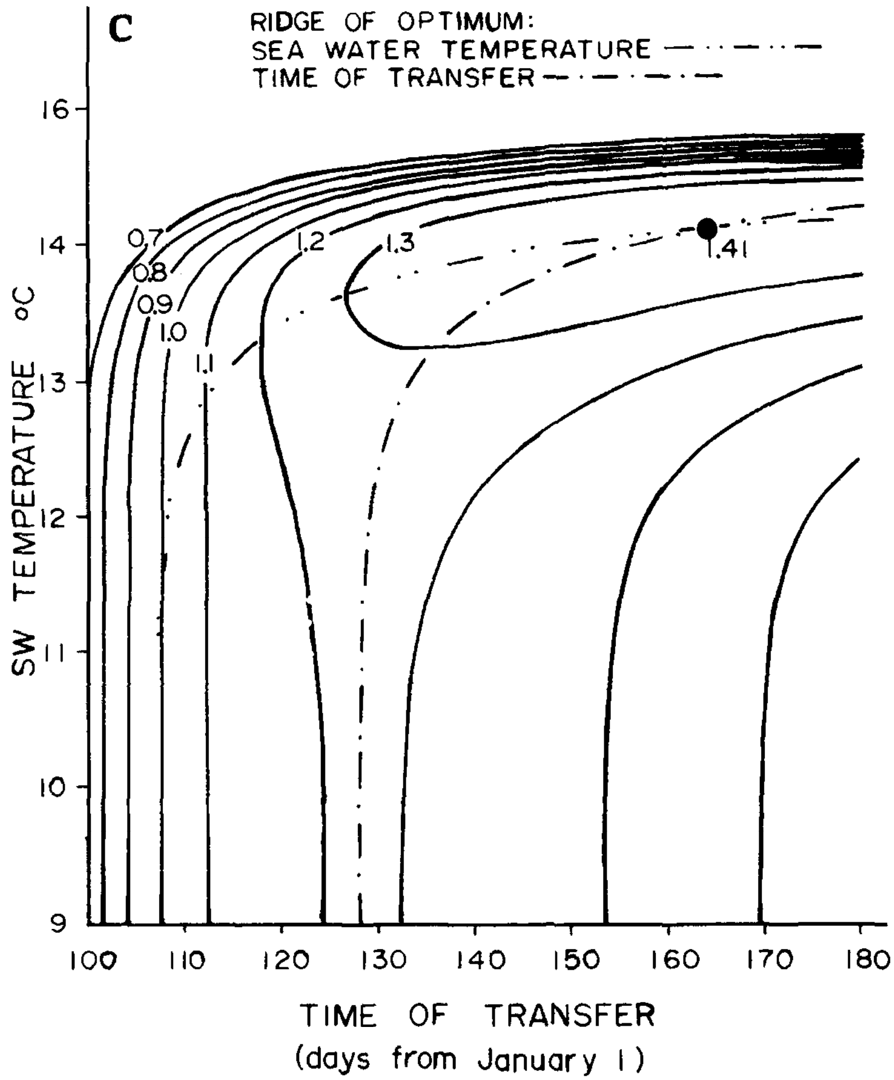

Fig. 3c. Contours on a plane through the response center of relative growth during the second through fourth weeks after transfer to sea water, slice at 9.7°C fresh water.

The fish in our experiment exhibited optimum seawater adaptability at 5–6 g, although hatchery release experiments using the same stock have suggested that marine survival continues to increase at release weights up to 12 g (Bilton, 1984). Because of the propensity for fall chinook to become descaled when reared in warm water, we recommend that intensive culture systems, such as commercial netpen farms, transfer fish to sea water at sizes less than 8 g and keep handling to a minimum beyond this size.

ACKNOWLEDGMENTS

We are indebted to J. Blackburn, W. Damon, R. Curtis and G. Ducommun for technical assistance and to M. Marshall and S. McKinnell for assistance with the response surface analysis and plotting.

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