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Effects of Temperature and Salinity on Egg Hatch of the Amago Salmon, *Oncorhynchus masou macrostomus*

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Responses of eggs of the amago salmon, *Oncorhynchus masou macrostmus*, to a series of temperature and salinity combinations were measured for percents of total and viable hatch and time to 50% hatch.

Hatch occurred at almost all tested combinations of temperature range (10 to 17.5 °C) and chlorinity range (0 to 5‰). Response surface analysis suggests that the maximum percent of viable hatch (*i.e.*, optimum) may be found at 13.8 °C combined with 1.0‰.

Time required to 50% hatch varied between 21.5 and 48 days after fertilization, and was inversely and exponentially related to the temperature. The effect of chlorinity on the time was statistically insignificant within the hatchable range of eggs.

Key words : temperature, salinity, fish egg, amago salmon, *Oncorhynchus masou macrostomus*.

The amago salmon, *Oncorhynchus masou macrostomus* GÜNTHER, is widely distributed in the rivers and sea of central and southern Japan, and is the species most likely to be chosen for fish propagation and culture.

Although temperature and salinity are factors which have a major effect on the survival of teleosts (KINNE 1964, BLAXTER 1969), there are few reports on the effects of these variables other than that which HONJOH (1977) has noted as the optimum temperature for hatch of the amago eggs. Hence, the present study was designed to determine the percents of total and viable hatch and the time to hatch of the eggs at various combinations of temperature and salinity.

Materials and Methods

The eggs were obtained on October 26, 1984, soon after fertilization from the Shiga Prefectural Samegai Trout Farm, and transported to our laboratory at a temperature of 10 °C, the same as the value at fertilization.

Experimental design was a 2 factor 4×4 factorial with a temperature range of 10 to 17.5 °C and a chlorinity range of 0 to 5‰ (Table 1). Subsamples of 20 eggs each were

put into 50mm diameter glass beakers with 80ml water. Two sets of four beakers each with a different ‰ of chlorinity were inserted in the four test constantly controlled temperature baths. Every day, when the beakers were checked any dead eggs were counted and removed. Two replicates of percents of total and viable hatch and time to 50% hatch were determined. Here, the objects of observation for viable hatch were limited to the normal larvae hatched without any abnormality.

For the experimental data, statistical treatment followed the analysis of variance of two-way layout (BLISS 1970). The relationship between the data and the two variables was calculated by the methods of orthogonal polynomial and shown as the regression equations and response surfaces. These techniques have come *in vogue* in recent years (ALDERDICE 1972).

Experimental chlorinities were obtained by dilution of synthetic sea salts with fresh water. Test water was changed every three days to keep the desired chlorinities. Slight aeration was used in all incubations.

Results

Percents of total and viable hatch

Results are shown in Table 1.

The percent of total hatch varied between 0 and 100% in all experimental combinations. Analysis of variance for these data proved to be significant for both temperature and chlorinity, but not for their interaction (Table 2). The relationship between total hatch (TH), temperature (T) and Chlorininity (C) was expressed by the second order equation:

$$TH = -539.16 + 88.45T - 3.20T^2 - 0.63C - 1.41C^2$$

but the term of interaction, TC, was omitted because it was statistically insignificant as mentioned above. From this equation, the response surface was constructed and shown as the isopleths of percent for a selected level such as 70, 60 and 50% (Fig.1). The highest percent was 72.9 % at 13.8 °C and 0.8 ‰ (point S in Fig.1). Changes in the two variables, both increases and decreases from these values, reduced the percent of total hatch.

The results of viable hatch were little different from those of total hatch (Tables 1 and 3).

Table 1. Percents of total and viable hatch of amago eggs incubated at 16 temperature salinity combinations

Temperature (°C)		Chlorinity (‰) 0		1		3		5	
D	EL	TH	VH	TH	VH	TH	VH	TH	VH
17.5	17.4±0.8	20	15	40	30	45	45	25	25
	17.4±0.5	15	15	0	0	15	15	20	15
15.0	14.6±1.9	75	75	75	75	65	65	55	55
	14.9±0.5	60	60	40	40	55	55	0	0
12.5	12.5±0.7	100	100	75	75	80	80	30	25
	12.4±0.4	80	80	70	70	60	60	20	10
10.0	10.2±0.5	5	5	30	30	15	15	20	20
	10.2±0.5	0	0	30	30	15	15	5	5

D: design. EL: experimental level (means±s.d.).

TH: percent of total hatch. VH: percent of viable hatch.

Table 2. Analysis of variance for data of percent of total hatch

Source	SS	DF	MS	F
Treatments	20,950.00	15	1,396.67	5.38**
Temperature	13,531.25	3	4,510.42	17.39**
Chlorinity	3,043.75	3	1,014.58	3.91**
Interaction	4,375.00	9	486.11	1.87
Regression				
Linear	1,941.25	2	970.63	3.74*
Quadratic	13,873.00	3	4,624.33	17.83**
Remainder	5,135.75	10	513.58	1.98
Residual	4,150.00	16	259.38	
Total	25,100.00	31		

Asterisk: significant (* $p<0.05$, ** $p<0.01$).

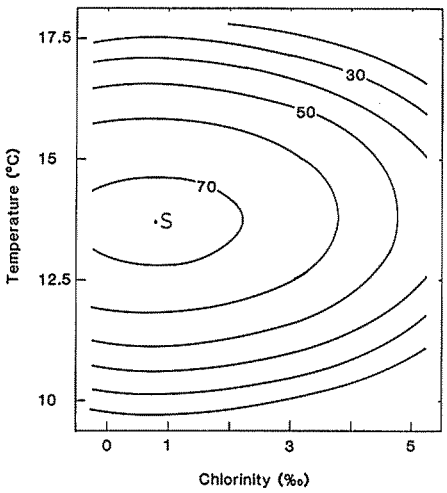

Fig. 1 Response surface showing isopleths of percent of total hatch in relation to temperature and chlorinity.

Table 3. Analysis of variance for data of percent of viable hatch

Source	SS	DF	MS	F
Treatments	22,261.72	15	1,484.11	6.11*
Temperature	13,452.34	3	4,484.11	18.46**
Chlorinity	3,564.84	3	1,188.28	4.89*
Interaction	5,244.54	9	582.73	2.40
Regression				
Linear	2,151.53	2	1,075.77	4.43*
Quadratic	14,762.69	3	4,920.90	20.25**
Remainder	5,347.50	10	534.75	2.20
Residual	3,887.50	16	242.97	
Total	26,149.22	31		

Asterisk: significant (* $P<0.05$, ** $p<0.01$).

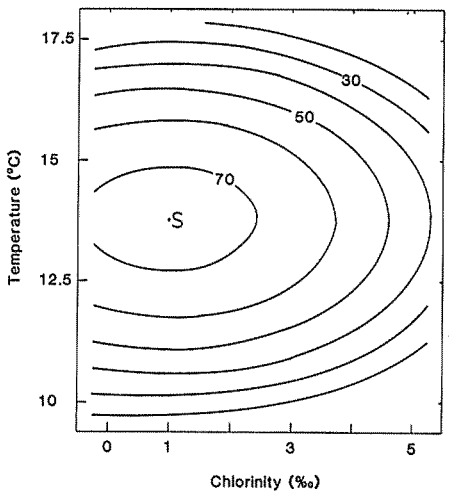

Fig. 2 Response surface showing isopleths of percent of viable hatch in relation to temperature and chlorinity.

The fitted equation was:

$$VH = -540.86 + 88.91T - 3.23T^2 + 3.53C - 1.80C^2$$

where VH=percent of viable hatch. The highest percent was 73.7% at 13.8°C and 1.0‰ (Fig.2).

Time to 50% hatch

The data varied between 21.5 and 48 days in all experimental combinations where hatch

occurred (Table 4). Analysis of variance for these data proved to be significant for temperature only (Table 5). The relationship between time (D) and temperature (T) was expressed by the second order equation:

$$D=127.05-11.29T+0.31T^2$$

The response surface is illustrated in Fig.3. The integrated value of temperature and time to 50% hatch was almost constant within the range of 412.5 to 452.9 °C • days.

Table 4. Time in days to 50% hatch of amago eggs incubated at 16 temperature-salinity combinations

	Chlorinity (‰)			
T (°C)	0	1	3	5
17.5	27.0 26.0	23.0 (19.5)	22.0 21.5	23.5 22.0
15.0	30.0 27.0	28.5 28.0	28.5 27.5	27.5 (30.0)
12.5	34.0 33.5	32.0 31.0	32.5 32.0	32.5 31.5
10.0	48.0 (46.0)	41.5 40.5	51.0 41.5	48.0 46.5

T: designed temperature.

Parenthesis: replacement for missing values to calculate ANOVA in Table 5.

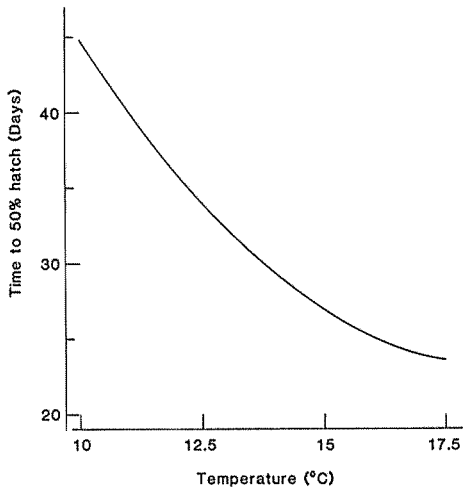

Fig. 3 Response surface showing time to 50% hatch in relation to temperature.

Table 5. Analysis of variance for data of time to 50 % hatch

Source	SS	DF	MS	F
Treatments	2,265.80	15	151.05	29.70**
Temperature	2,173.59	3	724.53	142.44**
Chlorinity	49.02	3	16.34	3.21
Interaction	43.20	9	4.80	0.94
Regression				
Linear	2,014.77	2	1,007.38	198.05**
Quadratic	161.44	3	53.81	10.58**
Remainder	89.60	10	8.96	1.76
Residual	66.13	13	5.09	
Total	2,331.93	28		

Asterisk: significant (* $p<0.05$, ** $p<0.01$).

Discussion

Responses of teleost eggs to changing temperature and salinity vary widely with the species (KINNE 1963, 1964). However, little is known about the present species.. HONJOH (1977) noted for the same species that the percent of total hatch was higher than 95% at temperature range of 13 to 16°C but the abnormality was the highest at 16°C, and then suggested that the optimum temperature for hatch was found to be within the range of 13 to 15°C. Our result that a temperature of 13.8°C produces the maximum percents of total and viable hatch (*i.e.*, optimum) are well in accord with his suggestion.

As for the time to 50% hatch, it is commonly understood that for teleost eggs the time is inversely and exponentially related to the incubation temperature within the thermal tolerance limits of the species. This applies to the amago eggs as well. The integrated value of 412.5—452.9°C • days coincides with that of the approximate 450°C • days reported by HONJOH (1977).

In the present study, the effect of chlorinity on the time to 50% hatch was statistically insignificant within the hatchable range of eggs. The same has been reported for Pacific herring, *Clupea pallasi*, which is a typical marine fish (ALDERDICE and VELSEN 1971). With changing salinities, while some acceleration or retardation of the time to 50% hatch has also been reported on several fishes, it is general that the effects of salinity are small in comparison with that of temperature (BLAXTER 1969, HOLLIDAY 1969, ROTHENTHALL and ALDERDICE 1976).

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