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Relation between juvenile survival and adult return in Japanese chum salmon around Hokkaido

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Erratum

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Equation (4) *in* Materials and Methods

$$S = 100(N_{rel} - N_1)/N_{rel} \longrightarrow S = 100N_1 / N_{rel}$$

Mistake in writing is regretted.

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Abstract

The return rate of adult chum salmon increased with the survival rate of juvenile chum salmon in each of five regions around Hokkaido. Both rates showed the lowest level in the year class spawned before the mid-1960's and the highest level in that spawned after the mid-1980's. The survival rate positively correlated to the return rate in each region. The regression lines between them show that 1/4 of one-year-old juvenile is expected to return as adults to Hokkaido. The juvenile survival decisively contributes the adult return.

Introduction

Chum salmon released from the rivers in Hokkaido spend several months in the coastal waters and migrate to North Pacific Ocean before it reaches one-year-old (Irie 1990). Survival of the chum salmon in this period (i.e. juvenile*) may largely affect to the number of adult return (Parker 1962; Fukuwaka and Suzuki 1999). Lack of information on the juvenile survival has been the bottleneck in understanding the adult return.

The purpose of this paper is to estimate the survival rate and to evaluate the relationship between the juvenile survival and the adult return around Hokkaido.

Materials and methods

Data were the number of juvenile released from hatcheries and the number of spawners caught by coastal fishery or at trapping sites of the hatcheries. They were compiled for each of five statistical regions around Hokkaido from 1950 to 1998 (Fig. 1). The release and catch statistics are extensively enough to understand the characteristics of population dynamics of chum salmon in Hokkaido, because wild population is scarce.

Chum salmon that is older than one year lives in ocean. In autumn, chum spawners return to their home rivers in concert with leaving the others resident in the ocean. This means that natural mortality and mortality by spawning separately act to the survival of chum salmon. So, the process of survival for fish older than one year in a year class can be expressed as

$$N_{t+1} = N_t e^{-M} - R_t \tag{1}$$

where N_t is the number of fish survived at t-year-old. R_t is the number of spawners at t-year-old, and M is the coefficient of natural mortality (year^{-1}) when it is assumed to be stable for chum salmon in the ocean.

N_t was derived by following equation modified from equation (1) by setting $N_{t_{max}+1}$ as zero.

$$N_t = (N_{t+1} + R_t)e^M \tag{2}$$

* This paper defines the chum salmon that is younger than one-year-old as juvenile.

M was estimated by following equation (Tanaka 1960; Kawai 1987)

$$M = 2.5 / t_{max} \tag{3}$$

where t_{max} is the maximum age of life span. For chum salmon, t_{max} corresponds to the maximum age of spawners. Table 1 shows t_{max} and M in each region.

The survival rate (%) of juvenile at one-year-old was derived by

$$S = 100(N_{rel} - N_1) / N_{rel} \tag{4}$$

where N_{rel} is the number of juvenile at release. Age of chum salmon at release in Hokkaido is about 0.5-year-old; therefore, S corresponds to the survival rate during the period from 0.5 to 1 year old.

The return rate of the adult in each year class was the percentage of the cumulative number of spawners caught at age to the number of released juvenile.

Results

The survival rate of juvenile in each region increased with fluctuation in all regions (Fig. 2). The increase initiated from the 1984 year class in the region A, and either of the 1965 or the 1966 year class in the regions B-E. The survival rate in each region was lowest in the year classes of 1957 (region D), 1964 (C) and 1965 (A, B, E), and highest in those of 1985 (D), 1987 (E), 1989 (C) and 1990 (A, B) (Table 2). The lowest survival rate ranged from 0.05% in the 1964 year class in the region E to 1.7% in the 1965 year class in the region E. The highest survival rate ranged from 12.6% in the 1985 year class in the region D to 40.8% in the 1990 year class in the region B.

Changes in the return rates of adult corresponded to those in the survival rates (Fig. 2). Year classes of the lowest or highest return rate appeared to correspond with those of the survival rates (Table 2). The lowest return rate ranged from 0.1% in the 1965 year class in the region E to 1.1% in the 1957 year class in the region D. The highest return rate ranged from 3.2% in the 1985 year class in the region D to 10.2% in the region A.

The survival rates and the return rates showed significantly positive correlation in all regions (Fig. 3). Slope of regression line in each region ranged from 0.23 to 0.28.

Discussion

Corresponding changes in the survival rates of juvenile and the return rates show that the juvenile survival decisively contributed to the extent of adult return. Fukuwaka and Suzuki (1998) suggested the importance of the juvenile survival on adult return in the population of northern Honshu Island along the coast of Sea of Japan.

The juvenile survival may vary with the size of fish released and the condition of coastal environment. That is, smaller fish and/or inappropriate environment will cause the lower survival rate of juvenile. To avoid it, the hatcheries in Hokkaido introduced the originally developed procedure of releasing larger juvenile at the proper timing in 1962 (Kobayashi 1980; Mayama 1985). After then, the juvenile released under this procedure increased year by year, and it consisted most of the juvenile released from Hokkaido in the end of the 1960's. Changes in the survival rates corresponded to the process of establishment of the procedure.

Some part of the changes in the survival rate of juvenile was probably derived from the equation (2) under the postulation that M (i.e. yearly survival rate) of the older fish (older than 1-year) was stable. In iteration by the equation (2), e^M is repeatedly multiplied. If M shifts as a whole or changes at some age(s), the survival rate of juvenile will change. Although the estimation of marine mortality and the detection of its change in salmonids have not succeeded, McGurk (1996) reported the allometric relationship between marine mortality and body weight of Pacific salmon including adult and juvenile. In addition, some papers pointed the possibility that change in marine environment affect the survival of Pacific salmon (Peterman 1978; Rogers 1984; Ishida *et al.* 1995; Kruse 1998).

The slopes of regression lines show that 1/4 of juvenile of one-year-old is expected to return as adults in total for a year class. If the process of juvenile survival in the coastal area around Hokkaido becomes clear, prediction of the adult return will become possible. More research on the relationship between the survival rate of juvenile and the coastal environment with reference to the regional difference is necessary.

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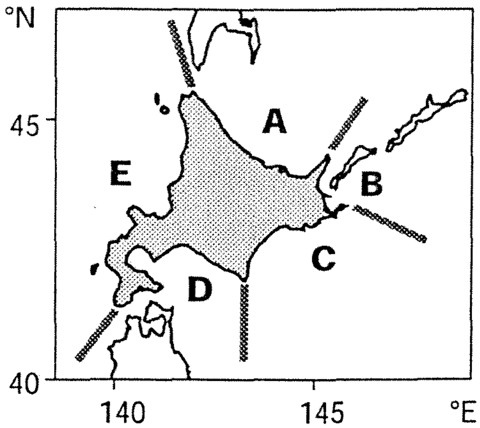

Figure 1. Regions of release and catch for chum salmon around Hokkaido. A, coast along Okhotsk Sea; B, Nemuro strait; C, east coast of Pacific Ocean, D, west coast of Pacific Ocean; E, coast along Sea of Japan.

Table 1. Maximum age of return and yearly mortality (M) of chum salmon released from Hokkaido. M is the mortality for fish older than one-year.

Region	Maximum age	M
A	7	0.357
B	6	0.417
C	7	0.357
D	6	0.417
E	6	0.417

Table 2. Lowest and highest rates of survival and return. YC, year class.

Region		Survival		Return	
		Lowest	Highest	Lowest	Highest
A	%	1.73	37.18	0.70	10.20
	(YC)	(1965)	(1990)	(1965)	(1990)
B	%	1.11	40.79	0.34	9.09
	(YC)	(1965)	(1990)	(1965)	(1990)
C	%	0.25	16.13	0.67	4.33
	(YC)	(1964)	(1989)	(1964)	(1989)
D	%	0.35	12.63	1.08	3.15
	(YC)	(1957)	(1985)	(1957)	(1985)
E	%	0.05	17.42	0.14	5.39
	(YC)	(1965)	(1987)	(1965)	(1987)

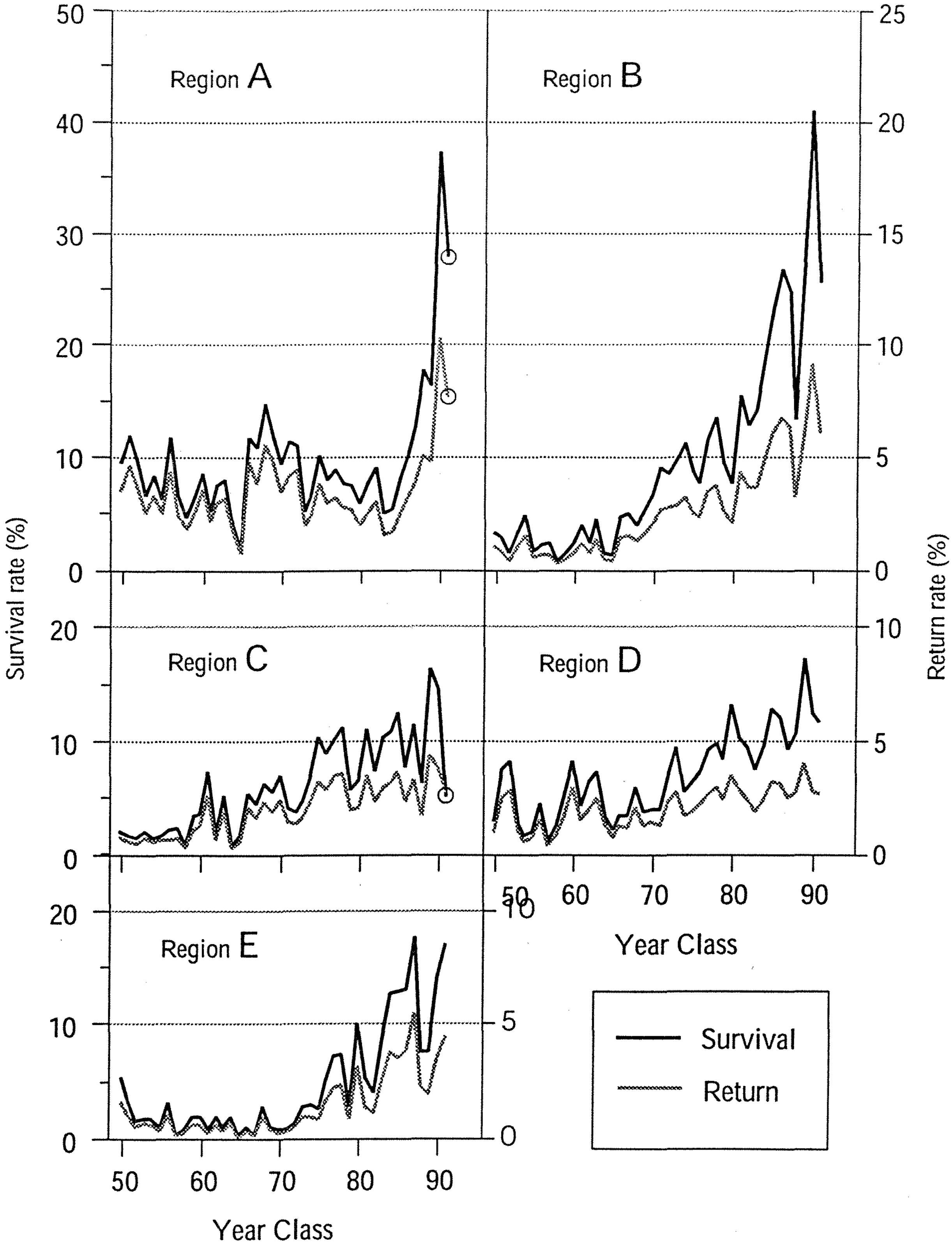

Figure 2. Survival rate of juvenile and return rate by the year class. ○, estimated from unconfirmed data.

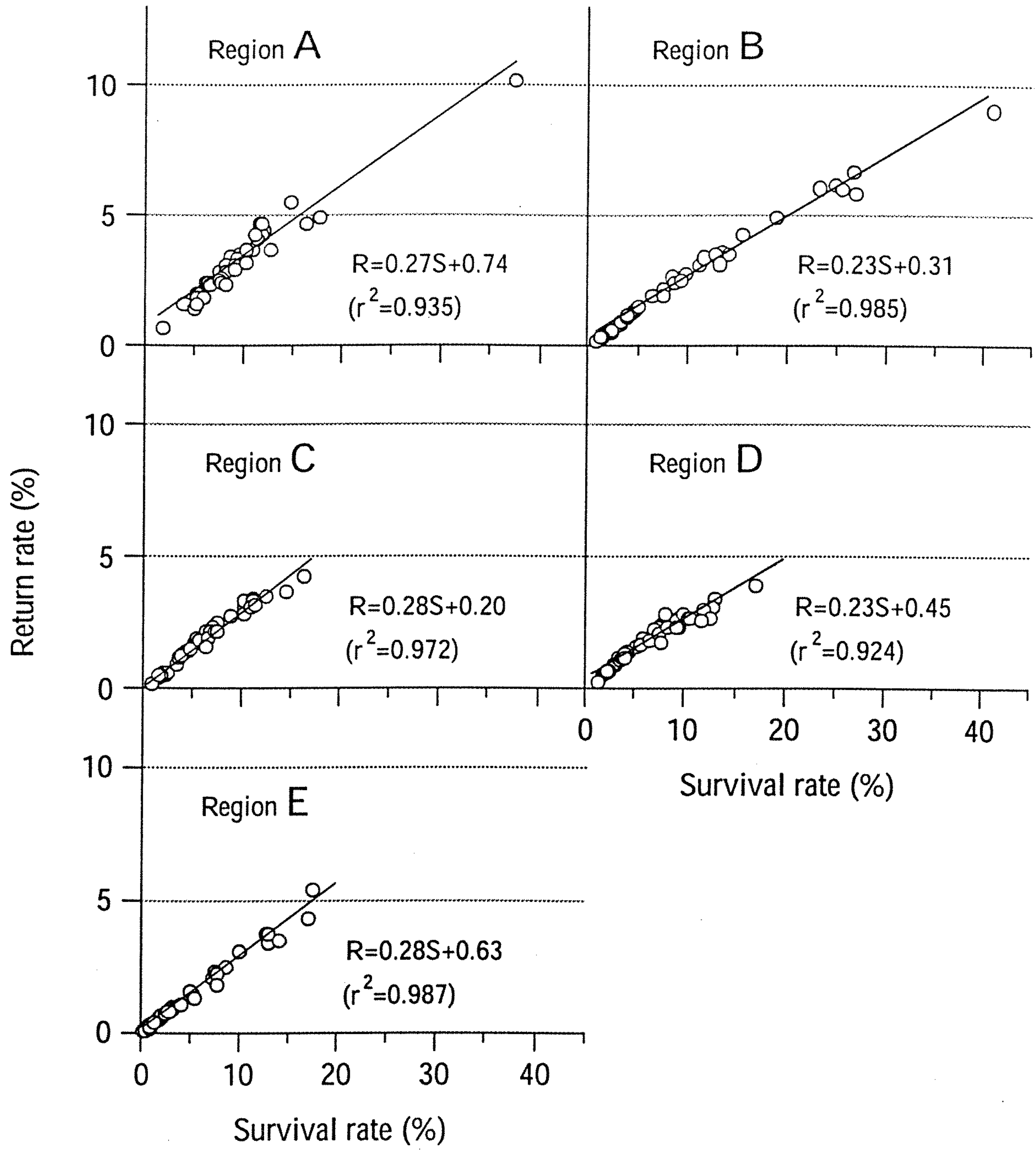

Figure 3. Relation between survival rate of juvenile (S) and return rate (R).