NPAFC
Doc. 335
Rev. _____

EARLY SEA MORTALITY OF CHUM SALMON JUVENILES IN THE JAPAN SEA COAST

by

Masa-aki Fukuwaka and Toshiya Suzuki

National Salmon Resources Center, Fisheries Agency of Japan,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan

Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISSION
by the
JAPAN NATIONAL SECTION

October 1998

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Fukuwaka, M., and T. Suzuki. 1998. Early sea mortality of chum salmon juveniles in the Japan sea coast. (NPAFC Doc. 335) 6 p. National Salmon Resources Center, Fisheries Agency of Japan, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan.

EARLY SEA MORTALITY OF CHUM SALMON JUVENILES IN THE JAPAN SEA COAST

ABSTRACT

We examined the early mortality of juvenile chum salmon to clarify population dynamics of hatchery-reared chum salmon in the Japan Sea coast. We calculated the survival rate using mark-and-recapture experiments during 10-50 days after release from the hatcheries along the Japan Sea coast of Honshu. Estimated daily survival rate during early sea life was 76.9 - approx. 100% day $^{-1}$. Mean survival during the whole sea life was 0.258% in 1988-1997. Early sea mortality of chum salmon accounted for 97.4% of the whole sea mortality. Results suggest that early sea mortality soon after release from hatcheries will determined a population level of returning adults of a cohort of chum salmon.

INTRODUCTION

In anadromous Pacific salmon, mortality is often extensively high soon after the entering into the sea (Pearcy 1992). Hatchery-reared chum salmon juveniles reach coastal waters within several days after release (Mayama et al. 1983; Kaeriyama 1986). Early sea mortality is much higher than subsequent stages in the life history of hatchery-reared chum salmon, thus it may determine adult population level (Bax 1983). Early sea distribution of chum salmon is restricted in nearshore regions in the Japan Sea coastal water (Fukuwaka and Suzuki In press). To clarify the population dynamics of hatchery-reared chum salmon in the Japan Sea coast, we examined early sea mortality of juvenile chum salmon using mark-and-recapture experiments in the coastal waters.

METHODS

Mark-and-recapture data sets for chum salmon juveniles were provided from the prefectural fisheries experimental stations along the Japan Sea coast of Honshu in 1992-1997 (Hokkaido Salmon Hatchery 1993-1997; National Salmon Resources Center 1998). Over 3 million fin-clipped juveniles were released from several private or prefectural hatcheries in 11 marking experiments in 1992-1997 (Table 1; Fig. 1). Surveys in coastal waters operated by the fisheries experimental stations of Yamagata, Niigata, Toyama, and Ishikawa Prefectures. Fisheries Agency of Japan financially supported these mark-and-recapture experiments. In 1992-1997, 1663 marked juveniles were recaptured by the prefectural fisheries experimental stations or commercial fishermen.

Daily survival rate was estimated using the equation:

$$\ln (m_t / n_t) = \ln (M / N_0) + (t - 0.5) \ln S,$$

where m_t is number of marked fish caught at time t, n_t is total number of marked and unmarked fish caught at time t, M is number of mark-and-released fish, N_0 is total number of marked and unmarked fish at release, and S is survival rate at time interval $t = 1$ (Nose 1961; cited by Tanaka 1985). We calculated survival rate using the liner regression analysis between log-transformed ratio of marked juveniles to all juveniles caught at samplings (ln (m_t / n_t)) over days after release (t). That method is approximately equivalent to the Jackson's positive method that is appropriate to the situation under variable catchability among samplings (Jackson 1936; Ito et al. 1980).

Early sea survival for 30 days was estimated from averaged daily survival rate. We assumed that the duration of coastal life was 30 days in the study site. Marked juveniles were recaptured within 0-35 days after release for 7 of 11 experiments (Table 2). Juveniles at 50 mm in fork length will grow to 75 mm at 27 days after using the specific growth rate 0.0151 in the study site (Fukuwaka and Kaeriyama 1994). Distribution of juveniles is changed at 75 mm with ontogeny to more offshore (Fukuwaka and Suzuki In press).

Total sea survival was averaged rough return rates of hatchery-released chum salmon during 1988-1997 in the Japan Sea coast of Honshu. The rough return rate was defined as the ratio of number of adults returned into coasts or rivers to number of juveniles released at 3 years before. Age at maturity was predominantly 4 years for chum salmon (Salo 1991). Hatchery-reared chum is ordinarily released at spring in the next year in the study site.

RESULTS

Estimated daily survival rate was 76.9-105.3% during early sea life of chum salmon released in the Japan Sea coastal area of Honshu (Table 2). Estimates for 2 experiments at Tedori River in 1993 and 1995 were over 100%. The upper 95% confidence limit was over 100% for an experiment at Sho River in 1997. Excepting these 3 estimates, daily survival rate was averaged as 88.9% (range 76.9-97.2%) during 43 days after release. This indicates that number of marked juveniles decreased to 2.93% of released juveniles in the first 30 days of sea life.

Total sea survival was 0.258% for the Japan Sea coast chum salmon population in 1988-1997. The mortality during the first 30 days (97.1%) accounted for 97.4% of total sea mortality. This indicated that coastal mortality exceeded subsequent ocean mortality.

DISCUSSION

We showed that early sea survival of hatchery-reared chum salmon was by far lower than subsequent ocean survival. Survivorship of many aquatic organisms during

early life is much lower than subsequent life. In some commercial fishes, population level is determined in early life called as “critical period” (Hjørt 1914, 1926). In anadromous Pacific salmon, mortality is often extensively high soon after they enter the sea (Pearcy 1992). Hatchery-reared chum salmon juveniles reach coastal waters soon after release (Mayama et al. 1983; Kaeriyama 1986). Early sea survival soon after release was extensively low in hatchery-reared chum salmon population (Bax 1983). Early sea mortality accounted for 97.4% of total sea (coastal and oceanic) mortality. Although the direct relationship between early sea survivorship and population level of cohorts could not be shown, extensively high mortality during early sea life would be mostly determined population level of returning adults.

Moreover, survival rate may become larger during early sea life. Larger or faster-growing juveniles survive in higher rate than the others (e.g., Healey 1982). Bax (1983) estimated daily survival in 2 or 4 days periods after release as 54-69%. Pearcy et al. (1989) estimated survival rates of juveniles within an estuary as 30% in 1-2 days period and 57% in 7-8 days period (equivalent to 45% and 93% day $^{-1}$). We estimated daily survival rate as 76.9-97.2% in 43 days periods after release for juvenile chum salmon. Daily survival estimate for longer period is larger in these reports. These suggest that survival in a few days period after release may critical for hatchery-reared chum salmon population.

Estimation errors would be attributed to small numbers of marked and unmarked juveniles caught in coastal surveys. Survival estimates for 3 of 11 experiments were above 100% or included 100% in the 95% confidence interval (Table 2). Number of marked juveniles recaptured in the coastal waters was largely variable among experiments. The measurement error of the ratio of recaptured juveniles to total caught juveniles will large at small number of total caught juveniles. However, the regression analysis could not evaluate the difference in measurement errors among surveys.

REFERENCES

Bax, N.J. 1983. Early marine mortality of marked juvenile chum salmon (*Oncorhynchus keta*) released into Hood Canal, Puget Sound, Washington, in 1980. Can. J. Fish. Aquat. Sci. 40:426-435.

Fukuwaka, M. and M. Kaeriyama. 1994. A back-calculation method for estimating individual growth of juvenile chum salmon by scale analysis. Sci. Rep. Hokkaido Salmon Hatchery 48: 1-9.

Fukuwaka, M. and T. Suzuki. In press. Role of a riverine plume as a nursery area of chum salmon *Oncorhynchus keta*. Mar. Ecol. Prog. Ser.

Healey, M. C. 1982. Timing and relative intensity of size-selective mortality of juvenile

chum salmon (*Oncorhynchus keta*) during early sea life. Can. J. Fish. Aquat. Sci. 39: 952-957.

Hjørt, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapp. P.-v. Réun. Cons. int. Explor. Mer 20: 1-228.

Hjørt, J. 1926. Fluctiuations in the year classes of important food fishes. J. Cons. int. Explor. Mer 1: 5-38.

Hokkaido Salmon Hatchery, Fisheries Agency of Japan. 1993-1995. Nihonkai ni okeru sake syoki-seikatsushi ni kansuru tyousa-kekka (1)-(3). Salmon Database No. 1-3. Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Sapporo.

Hokkaido Salmon Hatchery, Fisheries Agency of Japan. 1996-1997. Database on early life history of chum salmon population in Japan. Salmon Database 4-5. Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Sapporo.

Ito, Y., N. Hokyo, and K. Fujisaki. 1980. Doubutsu no kotaigun to gunshu. Tokai University Press, Tokyo.

Jackson, C. H. N. 1936. The analysis of animal population. J. Anim. Ecol. 8: 234-246.

Kaeriyama, M. 1986. Ecological study on early life of the chum salmon, *Oncorhynchus keta* (Walbaum). Sci. Rep. Hokkaido Salmon Hatchery 40: 31-92.

Mayama, H., J. Seki, and I. Shimizu. 1983. Studies on the chum salmon released in the Ishikari River System - II. On the seaward migration and inshore distributions of liberated fry in 1980-81. Sci. Rep. Hokkaido Salmon Hatchery 37: 1-22.

National Salmon Resources Center, Fisheries Agency of Japan. 1998. Database on early life history of chum salmon population in Japan. Salmon Database 6. National Salmon Resources Center, Fisheries Agency of Japan, Sapporo.

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. University of Washington Press, Seattle.

Pearcy, W.G., C. D. Wilson, A. W. Chung, and J. W. Chapman. 1989. Residence times, distribution, and production of juvenile chum salmon, *Oncorhynchus keta*, in Netarts Bay, Oregon. Fish. Bull. US 87: 553-568.

Salo, E.O. 1991. Life history of chum salmon (*Oncorhynchus keta*). p. 231-309. *In* C. Groot and L. Margolis [ed.] Pacific salmon life histories. UBC Press, Vancouver.

Tanaka, S. 1985. Suisan shigenngaku soron. Koseisha koseikaku, Tokyo.

Table 1. Number of fin-clipped chum salmon juveniles released from hatcheries along the Japan Sea coast of Honshu in 1992-1997.

Date of release	River	Clipped fin	Number of juveniles	Fork length (mm)	Body weight (g)
March 25, 1992	Miomote	Right and left ventral	470,347	50.1 ± 4.46	1.57 ± 0.417
March 15, 1993	Tedori	Adipose	100,000	61	1.9
April 5, 1993	Sho	Right and left ventral	314,000	61	2.0
March 31, 1994	Miomote	Adipose	236,000	50	1.0
April 7, 1994	Sho	Right and left ventral	315,000	62	2.3
March 7, 1995	Tedori	Adipose	312,000	69.3 ± 4.1	2.78
April 4, 1995	Sho	Right and left ventral	252,000	57.4 ± 4.6	1.75
March 18, 1996	Sho	Right and left ventral	260,000	52.5 ± 4.0	1.37
April 5, 1996	Miomote	Adipose	297,470	55.8 ± 3.5	1.11
March 13, 1997	Sho	Right and left ventral	316,000	46	0.9
March 17, 1997	Hime	Adipose	283,986	52.4 ± 3.7	1.1

Table 2. Estimated early sea survival (mean and 95% confidence interval) of fin-clipped chum salmon juveniles released from hatcheries along the Japan Sea coast of Honshu in 1992-1997.

Year	Origin	No. of recaptures	Duration (days after release)	Fork length at recapture (mm)	Survival rate (% day^{-1})
1992	Miomote R.	91	6 - 15	33.8 - 80.6	76.9 (72.4 - 81.8)
1993	Tedori R.	65	9 - 48	67.2 - 112.3	101.9 (100.4 - 103.4)
1993	Sho R.	24	4 - 30	46.0 - 92.7	84.5 (79.6 - 89.6)
1994	Miomote R.	501	0 - 43	38.1 - 81.6	94.9 (93.2 - 96.5)
1994	Sho R.	603	2 - 14	53 - 83	79.0 (74.9 - 83.4)
1995	Tedori R.	60	24 - 52	73 - 115	105.3 (103.3 - 107.4)
1995	Sho R.	94	1 - 26	47 - 85	88.0 (85.0 - 91.2)
1996	Sho R.	124	1 - 30	45.3 - 86.4	94.7 (92.2 - 97.2)
1996	Miomote R.	20	2 - 33	50.2 - 90.6	97.2 (95.1 - 99.3)
1997	Sho R.	11	1 - 35	41.9 - 71.0	99.5 (95.8 - 103.4)
1997	Hime R.	70	10 - 41	48.9 - 97.7	95.6 (93.3 - 97.9)

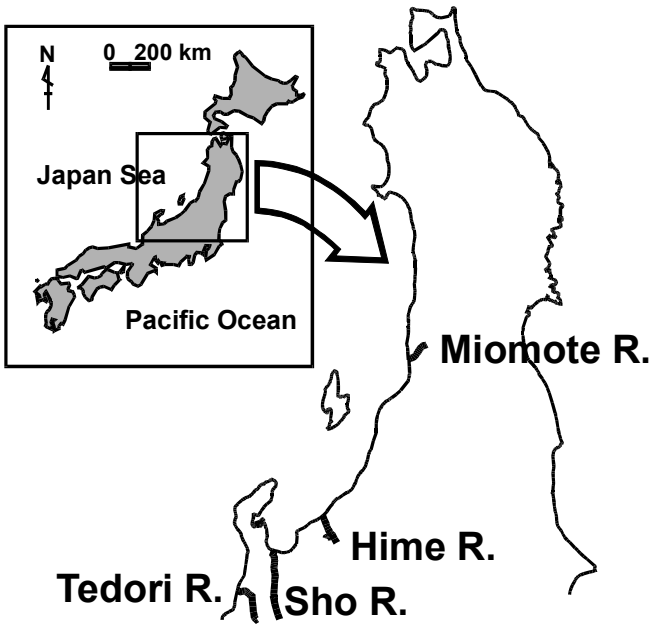

Fig. 1. Maps showing the study site along the Japan Sea coast of Honshu and rivers in which marked chum salmon juveniles were released in 1992-1997.