Distribution and abundance of juvenile chum salmon (*Oncorhynchus keta*) in Nemuro Bay, eastern Hokkaido, Japan

Kiyoshi Kasugai[1], Mitsuru Torao[1], Hiroshi Kakizaki[2], Hiroshi Adachi[3], Hiromi Shinhama[3], Yutaka Ogasawara[4], Shinji Kawahara[4], Tsutomu Arauchi[5] and Mitsuhiro Nagata[6]

1 Doto Research Branch, Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Nakashibetsu, Hokkaido 086-1164, Japan
2 Nemuro Salmon Enhancement Programs Association, Shibetsu, Hokkaido 086-1634, Japan
3 Notsuke Fisheries Cooperative Association, Betsukai, Hokkaido 086-1643, Japan
4 Betsukai Fisheries Cooperative Association, Betsukai, Hokkaido 086-0522, Japan
5 Nemuro Field Station, National Salmon Resources Center, Fisheries Research Agency, Nakashibetsu, Hokkaido 086-1109, Japan; Present address Miyako Station, Tohoku National Fisheries Research Institute, Miyako, Iwate 027-0052, Japan
6 Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Eniwa, Hokkaido 061-1433

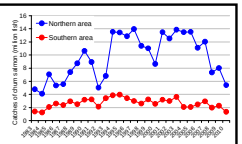
Background

◊ Catches of chum salmon in Hokkaido increased after 1970s and have remained at a higher level over 30 million since the 1990s.
In the Nemuro region, catches of chum salmon constitute about 30% of the whole catch in Hokkaido; however the catches in two areas of this region are different: the catch from the southern area is about one-third of that from the northern area.

◊ Mortalities of juvenile chum salmon in coastal waters just entering the sea are thought to be higher in their life histories. Therefore, one of the measures to obtain higher survival would to be decrease mortalities in coastal waters. Coastal environments and timing of entry the sea vary between regions, therefore release timings would vary between regions.

◊ It is recommended that releases of juvenile chum salmon should be started when sea surface temperatures (SSTs) in coastal waters are beyond 5˚C as the results from previous researches. However, juvenile chum salmon were distributed frequently at SSTs ranged from 8˚C to 13˚C in coastal waters and did not migrate toward off the sea in low SSTs, therefore the release timings were proposed to shift from time when SSTs ranged from 5˚C to 13˚C to time when SSTs ranged from 7˚C to 11˚C.

◊ We hypothesized that lower return of chum salmon to the southern Nemuro area may be because of a mismatch between release time and coastal environment. To examine our hypothesis, we released juvenile chum salmon, which reared as uniform size possibly to reduce size effects, at various times (late March–early May), and surveyed distribution and abundance in coastal waters. And, we investigated the suitability of coastal environments in the southern Nemuro area for juvenile chum salmon, examined whether release timings matched the coastal environments, and proposed a better release time for hatchery-reared fish to achieve a higher adult return.



Methods

◊ We released juvenile chum salmon, marked with alizarine-complexon (ALC), into Nishibetsu River in 2007–2010 (Table 1).
◊ In nearshore areas, we surveyed nine stations (T1–T3, N1–N3, F1–F3), at intervals of 10 days between late April and early July. In mid-July, surveys were conducted mainly in offshore areas survey stations (T4–5, N4–5, F3–6).
◊ In the littoral zone, four stations on the Betsukai area were set to collect juvenile chum salmon. Capture of juvenile chum salmon in the littoral zone were conducted with seine net at intervals of 10 days between late April and early July.

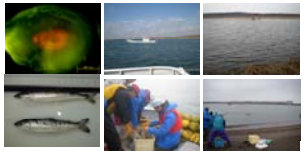
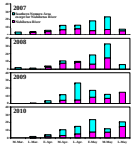
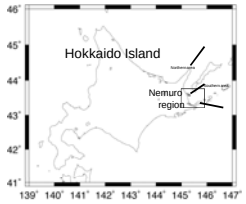


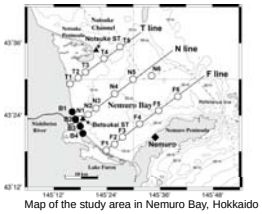
Table 1. Marked chum salmon released in four years. Fork length and body weight are shown by mean and standard error

Year	Mark	Date of release	Release sites	Number of released fish	Fork length (mm)	Body weight (g)
2007	Large & Small	20 Apr. 2007	Okunishibetsu	2,211,000	50.81 ± 0.28	1.302 ± 0.027
	Double	10 May 2007	Okunishibetsu	987,000	50.80 ± 0.44	1.229 ± 0.043
2008	Large	3 Apr. 2008	Okunishibetsu	1,057,000	52.26 ± 0.33	1.279 ± 0.028
	Double	17 Apr. 2008	Okunishibetsu	1,018,000	50.58 ± 0.39	1.172 ± 0.035
	Small	3 May 2008	Okunishibetsu	1,017,000	50.76 ± 0.34	1.197 ± 0.027
2009	Large	26 Mar. 2009	Okunishibetsu	862,000	51.78 ± 0.40	1.329 ± 0.036
	Double	14 Apr. 2009	Nishibetsu	860,000	53.93 ± 0.36	1.484 ± 0.034
	Small	17 Apr. 2009	Okunishibetsu	1,037,000	50.88 ± 0.42	1.179 ± 0.032
2010	Small	16 Apr. 2010	Okunishibetsu	1,085,000	49.98 ± 0.32	1.137 ± 0.023
	Double	24 Apr. 2010	Honbetsu	1,091,000	47.90 ± 0.24	0.965 ± 0.017



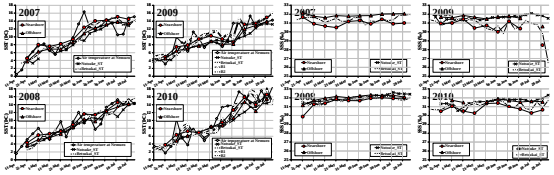
Number of juvenile chum salmon released into Nishibetsu River and the southern Nemuro area in 2007–2010





Map of the study area in Nemuro Bay, Hokkaido

Environment of Nemuro Bay



Changes in sea surface temperature at each sites and air temperature at Nemuro City in 2007-2010

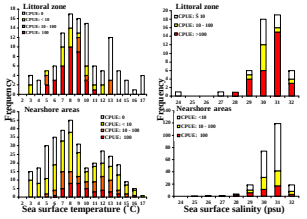
Changes in sea surface salinity at the Betsukai ST and Notsuke ST in 2007-2010

Table 2. Dates and durations of SSTs changes at Betsukai ST

Year	Dates when SSTs exceeded 6˚C	Dates when SSTs exceeded 8˚C	Dates when SSTs exceeded 13˚C	Periods with SSTs at 8-13˚C	Number of days with SSTs at 8-13˚C
2007	6 May	29 May	16 June	late May - early June	19
2008	7 May	5 June	12 July	mid-June - mid-July	38
2009	4 May	13 May	26 June	late May - late June	45
2010	6 May	10 June	21 June	early June - early June	12

At Betsukai ST, the dates when SSTs exceeded 6˚C were early May in four years (Table 2). The dates when sea surface temperatures (SSTs) exceeded 8˚C varied from year to year; the earliest and latest dates were in 2009 and 2010, respectively. SSTs rose over 12˚C rapidly in June. The dates when SSTs exceeded 13˚C in 4 years were the earliest in 2007 and latest in 2008. The durations of SSTs between 8˚C and 13˚C ranged from 12 to 45 days.

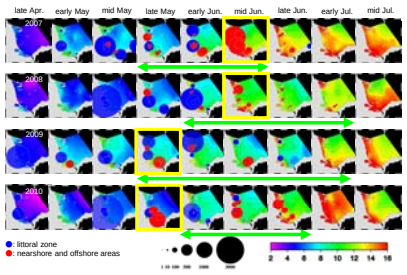
Environment at which juvenile chum caught



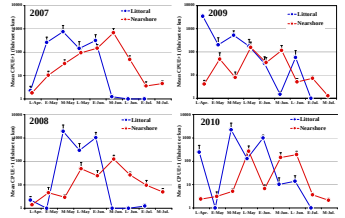
Frequencies of each category of juvenile chum salmon CPUE against SSTs and SSSs on each survey in the littoral zone and nearshore areas

Juvenile chum salmon were caught more frequently in nearshore areas when SST ranged 8–13˚C.

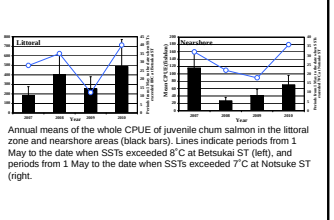
Changes in CPUE of juvenile chum salmon



Changes in CPUE of the whole chum salmon juvenile in Nemuro Bay. Arrows indicate periods that suitable SSTs (8–13˚C) covered in Nemuro Bay. Framed cells indicate times when CPUEs in nearshore areas were maximum.



Changes in mean CPUE of juvenile chum salmon in the littoral zone and nearshore areas in 2007–2010

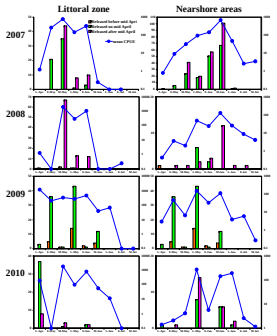


Annual means of the whole CPUE of juvenile chum salmon in the littoral zone and nearshore areas (black bars). Lines indicate periods from 1 May to the date when SSTs exceeded 8˚C at Betsukai ST (left), and periods from 1 May to the date when SSTs exceeded 7˚C at Notsuke ST (right.

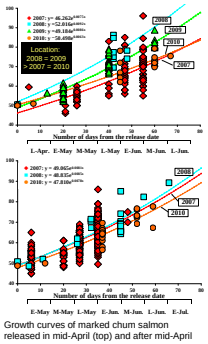
The high annual means of the whole CPUE in the littoral zone may be due to the delayed rise in SSTs at Betsukai ST, because juvenile chum salmon cannot migrate to nearshore areas at low SSTs.

The earliest rise in SSTs at Notsuke ST may spread the distribution of juvenile chum salmon out of Nemuro Bay, thereby decreasing the annual means of the whole CPUE in nearshore areas.

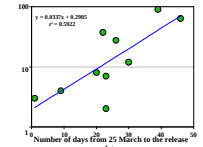
Marked juvenile chum salmon



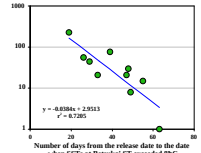
Bars indicate number of marked fish recaptured in the littoral zone and nearshore areas in 2007-2010.



Growth curves of marked chum salmon released in mid-April (top) and after mid-April (bottom)



Relationship between the number of days from 25 March to the release date and the log-transformed number of marked fish recaptured in the littoral zone



Relationship between the number of days from the release date to the date when SSTs at Betsukai ST exceeded 8˚C and the log-transformed number of marked fish recaptured in nearshore areas

Recapture of marked fish coincided with peaks in mean CPUE in the littoral zone and nearshore areas, and occurrences of marked fish did not coincided with the release dates.

Environmental variability in coastal waters during spring may influence the growth of marked fish release in mid-April more strongly than those released after mid-April.

In the littoral zone, the number of days from 25 March to the release date was correlated with the log-transformed number of marked fish; later the release date more the recaptured marked fish. The number of marked fish recaptured in nearshore areas increased with a decreased in the number of days from the release date to the date when SSTs at Betsukai ST exceeded 8˚C. High mortality may occur in the river and/or littoral zone before juvenile chum salmon migrate to nearshore areas.

Conclusions

◊ Annual means of the whole CPUE in the littoral zone may be high as rise of SSTs at Betsukai ST delayed, because juvenile chum should not migrate to nearshore area due to low SST.
◊ In the littoral zone, the number of marked chum salmon increased significantly as the release dates delayed; earlier release may cause higher mortality in the river.
◊ The earlier rise in SSTs at Notsuke ST may spread the distribution of juvenile chum salmon out of Nemuro Bay, and may result in decreasing annual mean of the whole CPUE in nearshore areas.
◊ In nearshore areas, the number of marked chum salmon increased as periods from the release date to the date when SSTs at Betsukai ST exceeded 8˚C. It might be suggested that mortalities were higher in the river and/or the littoral zone.
◊ Long stay in the river and/or littoral zone may cause high mortality.
◊ It is thought that if juvenile chums are released after mid-May, rearing period may be too short to grow sufficiently because of increase in SSTs at nearshore areas rapidly.
◊ We proposed that the release timing of juvenile chum salmon in Nemuro Bay should be shifted from late March–late May to late April to mid-May.