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Abstract

Stock origins of chum salmon caught in the western North Pacific Ocean (41-49°N, 155°E-180° lines) during spring 2006 were estimated by mitochondrial DNA marker. Chum salmon were most abundant in the central water (175°E and 180° lines) within the survey areas. Ocean age 2-4 chum salmon were dominant (84%), and young fish (ocean age 1) were relatively abundant in 180° line. The estimated stock composition of chum salmon was 14.5% Japanese, 65.0% Russian, and 20.5% North American stocks. The Japanese stock contribution was 4.4-11.1% in 165°E-175°E lines, while it was 27.6% in 180° line.

Introduction

Chum salmon (*Oncorhynchus keta*) is the most widely distributed salmon species in the Pacific Rim and an important commercial fisheries resource. Estimation of ocean distribution and stock origins of chum salmon in all seasons is important to clarify the stock assessment and the pattern of ocean migration. Since 1992, the Japanese research vessel *Kaiyo maru* has been collecting biological data of Pacific salmon and oceanographic data of the Bering Sea and North Pacific Ocean in summer, autumn, and winter (Nagasawa et al. 1994; Ueno et al. 1996; Ishida et al. 1998; Azumaya et al 2003, 2005; Fukuwaka et al. 2006).

The previous studies of genetic stock identification (GSI) by allozyme and mtDNA suggested that Japanese and Russian chum salmon stocks are predominant in chum salmon mixture in the central Bering Sea during summer and autumn (Urawa et al. 2004, 2005; Moriya et al. 2007). Winter high-seas surveys showed that young chum salmon (ocean age 1) are abundant in the western North Pacific Ocean, whereas old chum salmon (more than ocean age 2) are relatively abundant in the central North Pacific Ocean and Gulf of Alaska (Ueno et al. 1997, 1999; Ishida et al. 1998). The previous GSI studies suggested that Japanese young chum salmon inhabit the western North Pacific Ocean during the first winter, and migrate into

the Bering Sea during June and July (Urawa and Ueno, 1999; Urawa et al. 2001). However, information upon the marine distribution of chum salmon stocks during spring has not been sufficient.

Between April and June 2006, a first spring high-sea research cruise was conducted in the North Pacific Ocean and the Bering Sea by R/V *Kaiyo maru* to examine the stock condition of Pacific salmon (Morita et al. 2006). The objective of this report was to determine the stock origins and distributions of chum salmon caught on the 2006 spring research cruise in the western North Pacific Ocean using mtDNA marker.

Materials and methods

Fish samples

Samples of chum salmon were collected in the western and central North Pacific Ocean during the R/V *Kaiyo maru* spring research cruise between 22 April and 20 May, 2006 (Morita et al. 2006). One-hour trawl operations were made in the surface layer (from surface to 50 m in depth) with approximately 5 knots towing speed at 32 stations (41°-49°N, 155°E, 165°E, 170°E, 175°E, and 180° lines) (Fig. 1). Pectoral fin samples were collected from 867 chum salmon (Table 1) and fixed in 100% ethanol on board. At the laboratory of National Salmon Resources Center, Fisheries Research Agency, DNA was extracted from the fixed pectoral fin by a Puregene™ DNA Purification kit (QIAGEN Inc., Valencia, CA) following a manufacturer's instructions. Extracted DNA was dissolved in tris-EDTA buffer (TE; 10 mM Tris-HCl, 1 mM EDTA, pH 8.0).

MtDNA analysis

Thirty mtDNA haplotypes of chum salmon which was collected from the western North Pacific Ocean were detected by DNA microarray (Moriya et al. 2004) and assigned them to the population origins (Japanese, Russian or North American stocks) using the previously reported mtDNA baseline (Sato et al. 2004). This baseline was created by about 2,100 individuals from 48 populations of chum salmon in the Pacific Rim. In simulation studies using 48 baseline populations, estimates for the Japanese and North American regions maintained 96% accurate, whereas a estimate for Russian region had 88.5% accurate (Sato et al. 2005).

Results

Distribution and age component of chum salmon

A total of 1,832 individuals of chum salmon were caught from 30 of 32 stations (Table 1). Chum salmon were relatively abundant in the central water (175°E and 180° lines) (Fig. 1). The age composition of chum salmon was 15.1% age 0.1, 34.3% age 0.2, 30.2% age 0.3, 19.6% age 0.4, and 0.8% age 0.5 (Fig. 2). Ocean age 2-4 chum salmon were dominant (84%) in the survey area, and young chum salmon (ocean age 1) were relatively abundant in 180° line.

Genetic stock identification by DNA microarray

The estimated stock composition of entire chum salmon samples was 14.5% Japanese, 65.0% Russian, and 20.5% North American stocks (Table 2, Fig 3). Regional stock compositions of chum salmon in each age group were also estimated (Table 3). Ocean age 1

group was 16.5% Japanese, 30.0% Russian, and 53.5% North American stocks. Ocean age 2-4 groups were essentially Russia origin (56.0-71.5%). The GSI-estimated CPUE distribution indicated that Russian stock had highest biomass among chum salmon within the survey area (Fig. 4), being most abundant in the central water (175°E and 180° lines). The Japanese stock contribution was 4.4-11.1% in 165°E-175°E lines, while it was 27.6% in 180° line.

Discussion

During the winter period, young (ocean age 1) chum salmon were mainly distributed in the western North Pacific Ocean, while old chum salmon were mainly distributed around the Gulf of Alaska (Ueno et al. 1997; Ishida et al. 1998). Our spring survey indicated that chum salmon were relatively abundant in the central water (175°E-180° lines) within survey areas (the western North Pacific Ocean). Especially, young fish were most abundant in 180° line. Seawater temperature should be an important factor to affect the ocean distribution of salmon (Urawa et al. 2000). The mean sea surface temperature (SST) in western water (3.6°C at 165°E line and 4.3°C at 170°E line) was slightly lower than those in central waters (4.8°C at 175°E line and 5.5°C at 180° line) (data from Morita et al. 2006). This difference of SST may influence chum salmon distribution in the western North Pacific Ocean during the spring period.

It is noteworthy that North American stock was predominant (53.5%) in the ocean age 1 chum salmon that were mainly caught in 180° line, although Russian stock was predominant (56.0-71.5%) in the ocean age 2-4 groups. It is uncertain where the North American young fish stayed during the first winter before reaching to the central water. The stock composition of wintering ocean age 2-3 chum salmon on 180° line estimated was 8% Japanese and 90% Russian stocks (Urawa and Ueno, 1999). Thus, some Russian chum salmon stocks may stay in the western and central North Pacific Ocean through winter and spring.

The estimated contribution of Japanese chum salmon was 4.4-11.1% in 165°E-175°E lines, and 27.1% in 180° line. Urawa et al. (2001) estimated stock compositions of ocean age 1 chum salmon in the western North Pacific Ocean (160°E and 165°E lines) by allozyme. These overwintering young chum salmon comprised 34% Japanese stock on 160°E line and 47% Japanese stock on 165°E line. These results suggest that Japanese ocean age 1 chum salmon is mainly distributed in western North Pacific Ocean during winter, and perhaps they migrate east to the central North Pacific Ocean before entering in the Bering Sea in early summer.

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Table. 1. A list of chum salmon samples caught in the western and central North Pacific Ocean during spring research cruise R/V *Kaiyo maru*. NA: No analysis.

Station	Latitude	Longitude	Date	Number of catches	Number of genetic samples
1	41°01’N	154°47’E	2006/4/24	3	3
2	41°58’N	155°13’E	2006/4/24	15	13
3	42°56’N	155°12’E	2006/4/25	5	5
4	43°51’N	155°10’E	2006/4/25	0	0
			Subtotal	23	21
5	48°52’N	164°56’E	2006/4/28	6	6
6	47°50’N	164°59’E	2006/4/28	3	3
7	46°54’N	165°11’E	2006/4/29	16	16
8	45°50’N	165°06’E	2006/4/29	2	2
9	45°00’N	164°44’E	2006/4/30	24	24
10	44°00’N	164°49’E	2006/4/30	99	56
11	43°05’N	164°48’E	2006/5/1	44	44
			Subtotal	194	151
12	43°06’N	169°49’E	2006/5/2	52	52
13	43°55’N	169°47’E	2006/5/2	8	8
14	44°51’N	169°53’E	2006/5/3	15	14
15	45°51’N	169°56’E	2006/5/3	1	1
16	46°53’N	170°07’E	2006/5/4	4	4
17	47°56’N	169°46’E	2006/5/4	6	6
18	49°08’N	170°06’E	2006/5/5	13	13
			Subtotal	99	98
19	49°09’N	174°59’E	2006/5/6	4	4
20	48°01’N	174°46’E	2006/5/6	102	59
21	46°51’N	175°01’E	2006/5/7	391	60
22	45°58’N	174°48’E	2006/5/7	14	13
23	45°04’N	174°49’E	2006/5/8	52	51
24	44°23’N	174°48’E	2006/5/8	106	60
25	43°06’N	174°50’E	2006/5/9	89	63
			Subtotal	758	310
26	43°00’N	179°47’E	2006/5/10	170	64
27	43°51’N	179°56’W	2006/5/10	97	69
28	45°06’N	179°50’W	2006/5/11	142	NA
29	46°02’N	179°46’W	2006/5/11	264	59
30	46°55’N	179°48’W	2006/5/12	65	65
31	47°50’N	180°00’	2006/5/12	20	20
32	48°51’N	179°59’E	2006/5/13	0	0
			Subtotal	758	287
Total				1,832	867

Table 2. Estimated regional contributions of chum salmon caught in the western and central North Pacific Ocean during spring research cruise of the R/V *Kaiyo maru* 2006. The mean estimate and standard deviation (S.D.) were calculated from 1,000 resamplings of mixture and baseline samples.

Line	N	Japan		Russia		North America	
		mean	S.D.	mean	S.D.	mean	S.D.
155º E	21	0.112	0.110	0.451	0.310	0.438	0.278
165º E	151	0.044	0.035	0.731	0.242	0.225	0.238
170º E	98	0.111	0.054	0.661	0.242	0.228	0.232
175º E	310	0.108	0.047	0.621	0.191	0.271	0.181
180º E	287	0.276	0.066	0.523	0.177	0.202	0.165
Total	867	0.145	0.038	0.650	0.178	0.205	0.169

Table 3. Estimated regional contributions of chum salmon in each age group caught in the western and central North Pacific Ocean during spring research cruise of the R/V *kaiyo maru* 2006. The mean estimate and standard deviation (S.D.) were calculated from 1,000 resamplings of mixture and baseline samples.

Age	N	Japan		Russia		North America	
		mean	S.D.	mean	S.D.	mean	S.D.
0.1	135	0.165	0.053	0.300	0.191	0.535	0.182
0.2	234	0.130	0.049	0.688	0.207	0.183	0.199
0.3	290	0.148	0.056	0.715	0.163	0.138	0.152
0.4	197	0.144	0.063	0.560	0.241	0.296	0.222
0.5	8	0.590	0.211	0.185	0.207	0.225	0.184

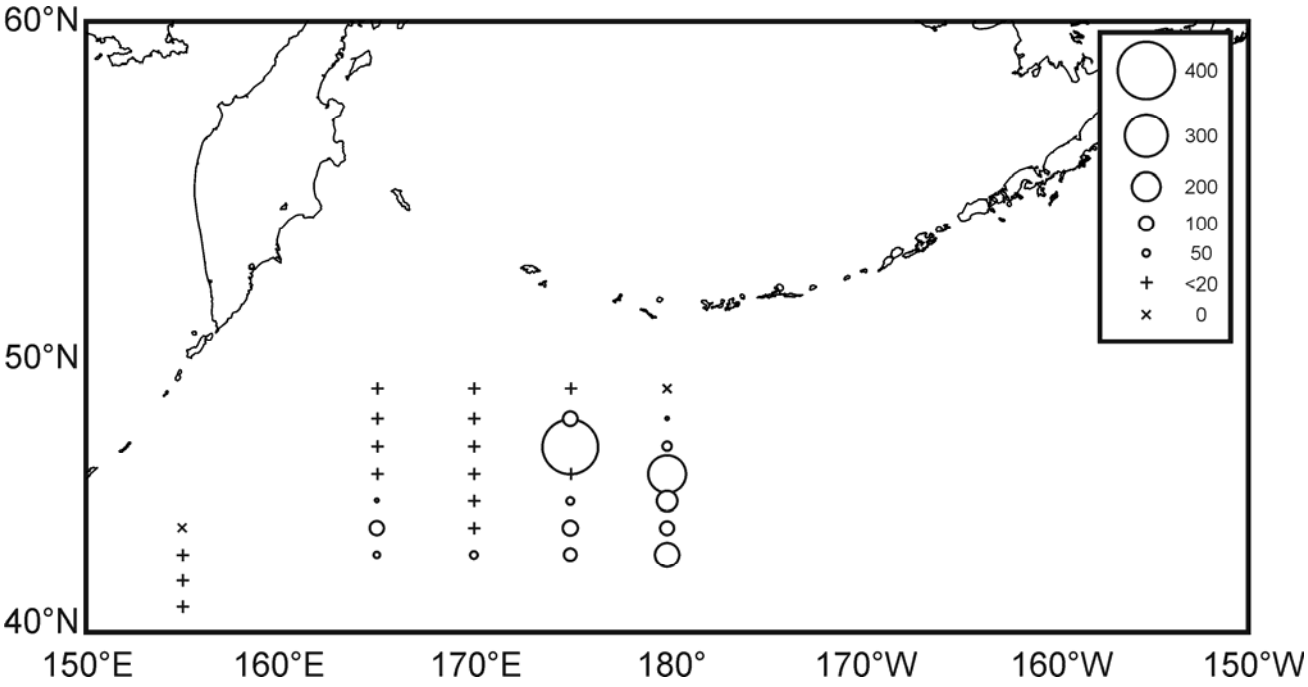

Fig. 1. Number of chum salmon caught by 1-h trawl (CPUE) in the western North Pacific Ocean during spring research cruise of 2006.

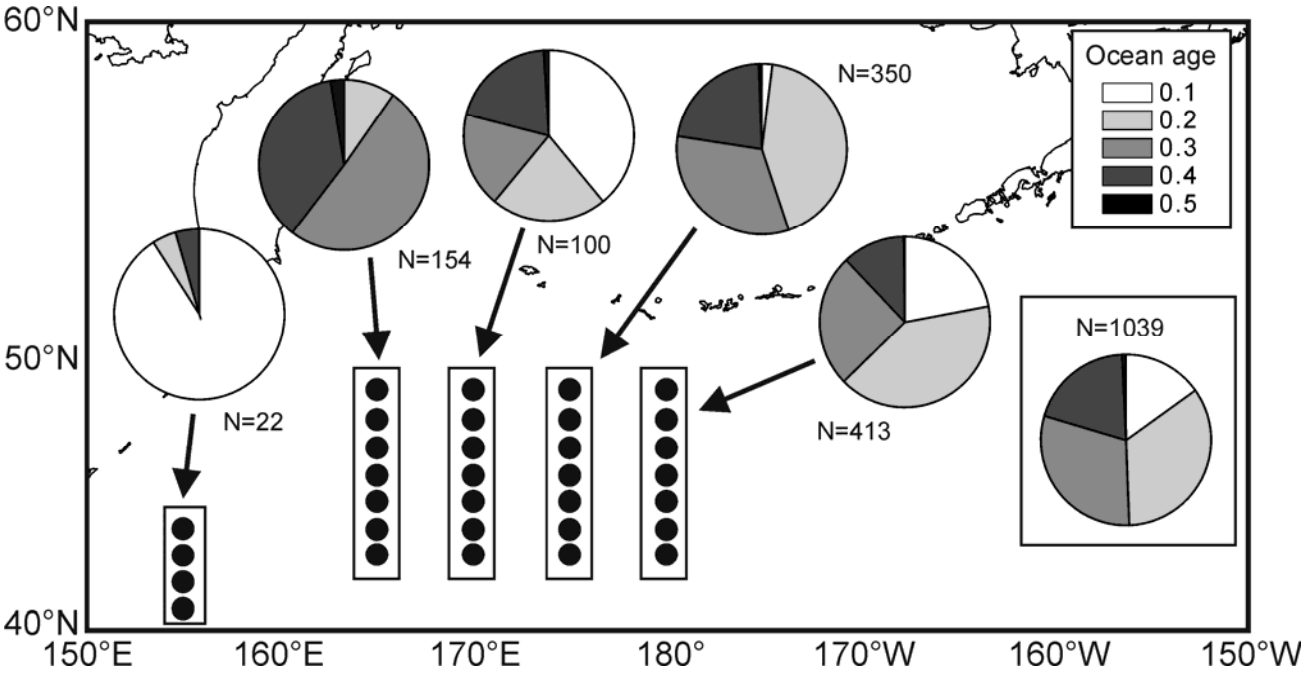

Fig. 2. Percent composition of ocean age in chum salmon caught in the western North Pacific Ocean during spring research cruise of 2006.

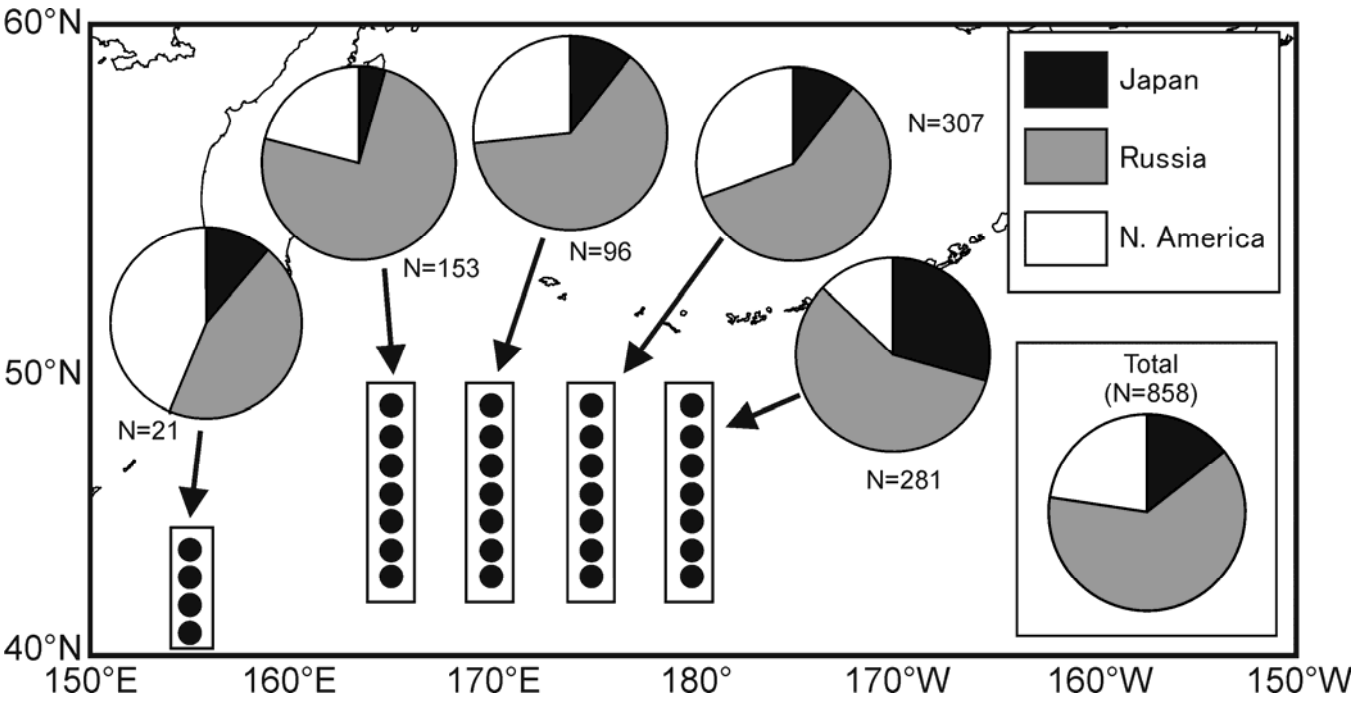

Fig. 3. Genetic-estimated stock composition (%) of chum salmon caught in the western North Pacific Ocean during spring research cruise of 2006.

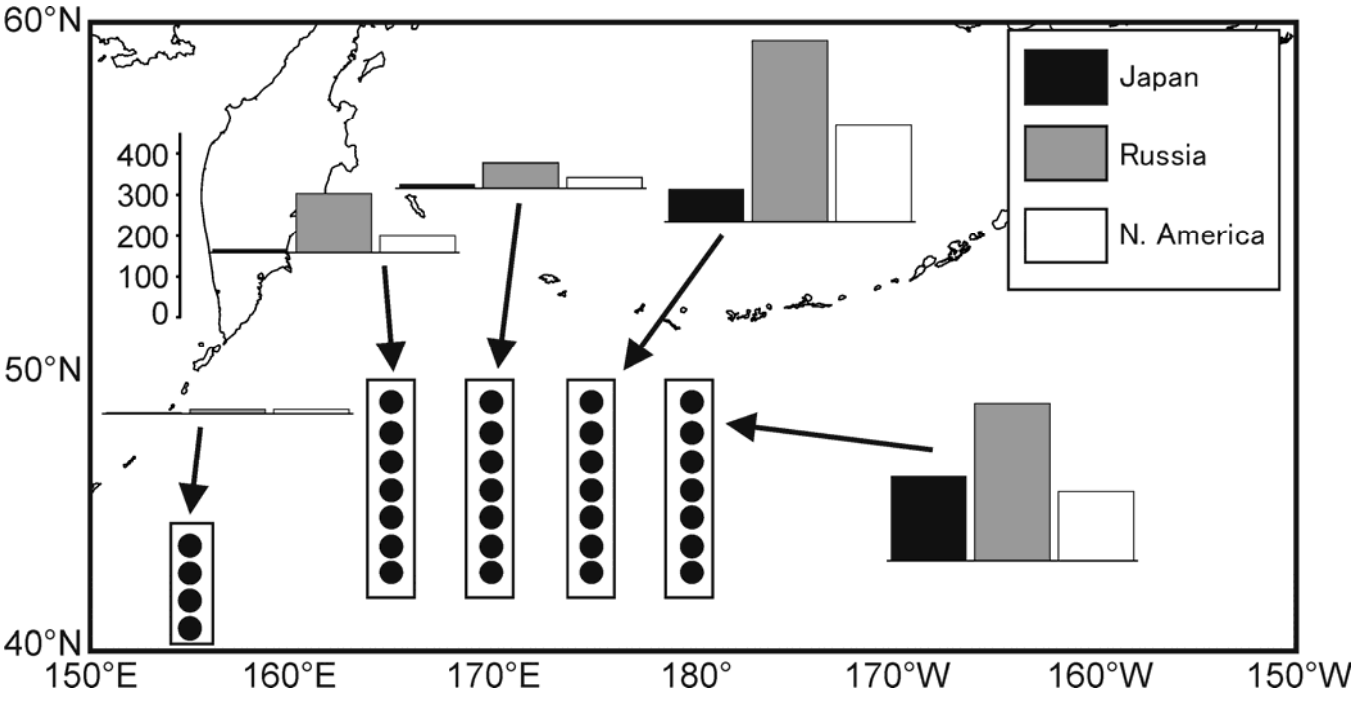

Fig. 4. Genetic-estimated CPUE of chum salmon by stock origin in the western North Pacific Ocean during spring research cruise of 2006. CPUE means number of catches per 1-h trawl.