2000年秋にオホーツク海南西部で採集されたサケ幼魚の起源

メタデータ	言語: English 出版者: さけ・ます資源管理センター 公開日: 2024-04-05 キーワード (Ja): キーワード (En): juvenile chum salmon; distribution; genetic stock identification; otolith mark; Okhotsk Sea 作成者: 浦和, 茂彦, 関, 二郎, 川名, 守彦, 斎藤, 寿彦, Crane, Penelope A., Seeb, Lisa W., 福若, 雅彰, Akinichev, Elena メールアドレス: 所属:
URL	https://fra.repo.nii.ac.jp/records/2001591

Bulletin of the National Salmon
Resources Center, No. 8: 9-16
March 2006

さけ・ます資源管理センター
研究報告　第8号　9-16頁
2006年3月

Origins of Juvenile Chum Salmon caught in the Southwestern Okhotsk Sea during the Fall of 2000

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Abstract.－ Genetic stock identification (GSI) and thermal otolith marking techniques were used for determining the stock origin of juvenile chum salmon (*Oncorhynchus keta*) (age 0.0) caught in the southwestern Okhotsk Sea (48-51˚N, 146-150˚E) in October 2000. The GSI results using an Asian baseline indicated that the stock composition of juvenile chum salmon was 21% Japan, 22% Amur River, 25% Sakhalin, and 31% northern Russia (Magadan/Kamchatka) stocks. Seven otolith marked chum salmon (3.4%) were found among the samples. These marked fish were released from the Bereznykovsky Hatchery (n=6) in Sakhalin and the Ozerky Hatchery (n=1) in western Kamchatka. These results suggested that Russian stocks were dominant among juvenile chum salmon in the sampling area in the fall of 2000.

Key words: juvenile chum salmon, distribution, genetic stock identification, otolith mark, Okhotsk Sea

Introduction

Juvenile chum salmon (*Oncorhynchus keta*) are abundant in the Okhotsk Sea during the summer and fall (Ueno 1997; Melnikov et al. 1999a, 1999b; Lapko and Glebov 2001). A genetic stock identification (GSI) study suggested that Japanese stocks are dominant among juvenile chum salmon caught in the southern Okhotsk Sea in the fall of 1993 (Urawa et al. 1998, 2001), but other stock identifications have not been conducted for juvenile salmon in this water.

Thermal and dry markings of salmonid otoliths have been well developed as a remarkable tool to determine the hatchery origin of salmon. Now large numbers of otolith-marked salmon are annually released from hatcheries in Pacific rim countries. In the spring of 2000, approximately 14 million thermally-marked chum salmon fry were released from 5 hatcheries in Japan, and 32 million chum fry with dry or thermal marking were released from 7 hatcheries in Russia (Table 3).

The present study was conducted to determine stock origin of juvenile chum salmon caught in the southwestern Okhotsk Sea in the fall of 2000 by using genetic and otolith marks.

Materials and Methods

Fish samples

Trawl surveys were conducted at 10 sampling stations in the southwestern Okhotsk Sea (45-51˚N, 146-150˚E) and one station (44˚N, 150˚E) in the North Pacific Ocean off the Kuril Islands by R/V *Torishima* during October 13-28, 2000 (Table 1, Fig. 1)(Saito et al. 2001). The size of the mid-water rope trawl was 87 m in net length and 41 m in head-rope length. The trawl was towed for 60 min at average 3.5 knot. The captured juvenile chum salmon (age 0.0) were preserved in a deep freeze (-35˚C) until analyses. In laboratory, the fork length, body weight and gonad weight of each fish were recorded, and scales were removed to confirm their age.

Contribution A No. 42 from the National Salmon Resources Center.

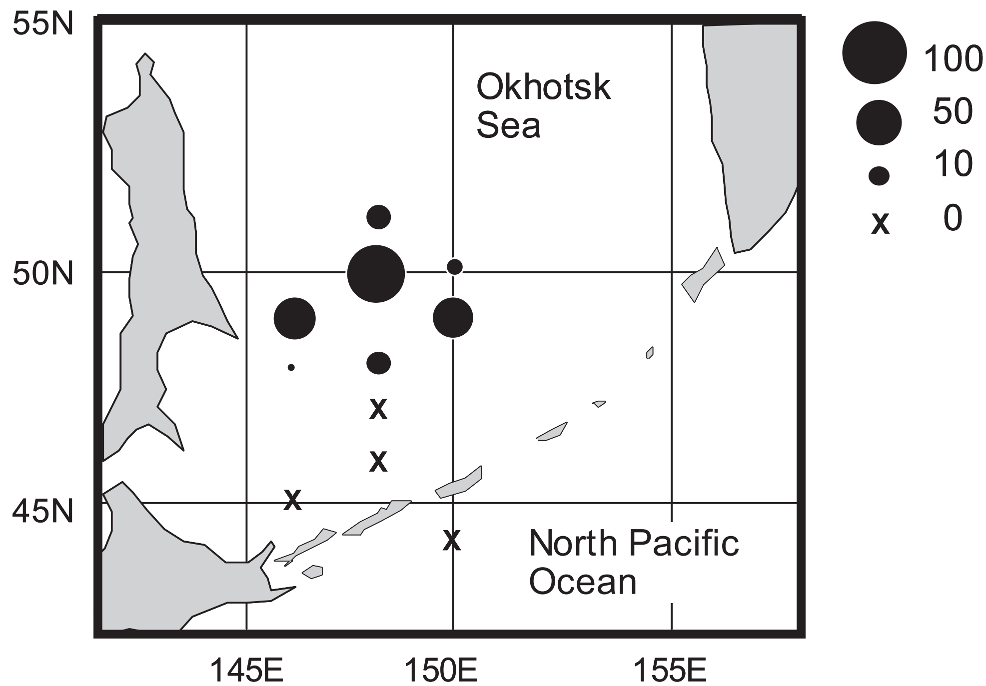

Fig. 1. CPUE distribution of juvenile chum salmon in the southern Okhotsk Sea in October 2000. CPUE means the number of fish caught by 1-h trawl at 3.5 knots.

Table 1. Sampling location, date and number of juvenile chum salmon (age 0.0) caught in the Okhotsk Sea in the fall of 2000.

Sampling location			Date of sampling	Number of fish samples	Number of otolith marked fish	
Station #	Latitude (N)	Longitude (E)			Bereznykovsky Hatchery	Ozerky Hatchery
1	45˚00´	146˚02´	Oct. 13	0	0	0
2	46˚01´	148˚00´	Oct. 14	0	0	0
3	47˚00´	148˚00´	Oct. 14	0	0	0
4	48˚01´	147˚59´	Oct. 16	15	0	0
5	48˚00´	146˚02´	Oct. 16	2	0	0
6	49˚00´	146˚03´	Oct. 21	43	0	0
7	51˚00´	148˚01´	Oct. 23	15	1	0
8	50˚01´	148˚00´	Oct. 24	82	2	1
9	49˚01´	150˚01´	Oct. 25	41	3	0
10	49˚59´	150˚02´	Oct. 25	8	0	0
11	44˚02´	150˚01´	Oct. 28	0	0	0

tal otoliths, muscle, heart, and liver were collected from each fish. The sagittal otoliths were dried and kept in cell well plates until the detection of otolith makers. The other tissues (muscle, heart, and liver) were immediately frozen in -80˚C freezer for genetic analysis.

GSI analysis

Genetic samples were examined for protein electrophoretic variation on horizontal starch gels using standard procedures described by Aebersold et al. (1987). Alleles were compared and standardized for 20 polymorphic loci (Table 2). We used Asian baseline data set (43 stocks/20 loci) collected by Winans et al. (1994), Wilmot et al. (1998) and present study (Appendix). Estimates of stock contributions were made with a conditional maximum likelihood algorithm (Pella and Milner 1987) using the Statistics Program for Analyzing Mixtures (SPAM version 3.5, Debevec et al. 2000). Standard deviations and 90% confidence intervals were estimated by 1,000 bootstrap resamplings of the baseline and mixture samples. Estimates were made to individual stocks and than pooled to regional stock groups: Japan, Sak-

Table 2. Loci and alleles pooled for Asian baseline of chum salmon.

	Allele								
Locus	1	2	3	4	5	6	7	8	9
sAAT-1,2*	100/113	120/125	65		84/80/95				
mAAT-1*	-100	-120/-110	-70						
mAH-3*	100/140/115	124							
ALAT*	100/98/fast	93/90	78						
ESTD*	100	91/80	110/106						
G3PDH-2*	100/132	90							
GPI-B1,2*	100	fast	40						
GPI-A*	100	slow	Fast						
mIDHP-1*	100	60	140	20	85				
sIDHP-2*	100/65	35	85	25	20	110	28		45
LDH-A1*	100	50	110/0						
LDH-B2*	100/60	120/115							
sMDH-A1*	100	200	400	10					
sMDH-B1,2*	100/110	72/85/95	50/20	fast>110					
mMEP-2*	100/75	122							
sMEP-1*	100	90							
MPI*	100	94/91/95/97	110	80/86		74			
PEPA*	100	90	113						
PEPB-1*	-100	-146	-126	-127	-72/-50				
PGDH*	100	88/84	104/106/110	95					

Table 3. A list of otolith-marked chum salmon fry (1999 brood year) released from hatcheries in Japan and Russia during the spring of 2000. These data are available through the North Pacific Anadromous Fish Commission (NPAFC) Working Group on Salmon Marking website (http://npafc.taglab.org/).

ID #	Mark type[*1]	Date released	Country	State/ Province	Region released	Facility	Release site	Total # released	RBr code[*2]
J99-01	TM	Mar. 16-Apr. 10	Japan	Hokkaido	Japan Sea coast	Chitose Hatchery	Chitose River	4,914,000	1:1.2,2.6n
J99-02	TM	May19-22	Japan	Hokkaido	West Pacific coast	Shizunai Hatchery	Shizunai River	311,000	1:1.2,2.3
J99-03	TM	Mar. 3-May 17	Japan	Hokkaido	West Pacific coast	Shizunai Hatchery	Shizunai River	3,113,000	1:1.2,2.3
J99-04	TM	May 10	Japan	Hokkaido	West Pacific coast	Shizunai Hatchery	Shizunai River	15,000	1:1.2,2.3+3.5
J99-05	TM	May 31-Jun. 3	Japan	Hokkaido	West Pacific coast	Shikiu Hatchery	Shikiu River	824,000	1:1.2,2.3n -3.3n
J99-06	TM	Apr. 20-May 31	Japan	Hokkaido	West Pacific coast	Shikiu Hatchery	Shikiu River	360,000	1:1.2,2.3n -3.5n
J99-07	TM	Apr. 20-May 31	Japan	Hokkaido	West Pacific coast	Shikiu Hatchery	Shikiu River	378,000	1:1.2,2.1n
J99-08	TM	May 1	Japan	Hokkaido	Nemuro Strait coast	Ichani Hatchery	Kunbetsu River	1,085,000	1:1.2,2.4n
J99-09	TM	Apr. 19-May 31	Japan	Hokkaido	Nemuro Strait coast	Ichani Hatchery	Ichani River	3,503,000	1:1.2,2.8n
R99-01	TM	unknown	Russia	Magadan	Tauy Bay	Arman Hatchery	Arman River	4,100,000	1:1.5n
R99-02	DM	unknown	Russia	Magadan	Tauy Bay	Yana Hatchery	Yana River	39,100	1:1.6
R99-04	DM	unknown	Russia	Magadan	Tauy Bay	Ola Hatchery	Ola River	302,000	1:1.5
R99-06	DM	unknown	Russia	Magadan	Tauy Bay	Ola Hatchery	Ola River	112,000	1:1.5n
R99-07	DM	unknown	Russia	Magadan	Tauy Bay	Ola Hatchery	Ola River	43,000	1:1.5n+2.17
R99-08	TM	unknown	Russia	Magadan	Tauy Bay	Ola Hatchery	Ola River	3,500,000	1:1.5
R99-09	TM	unknown	Russia	Magadan	Tauy Bay	Tauy Hatchery	Tauy River	740,000	1:1.5+2.2
R99-12	DM	unknown	Russia	Kamchatka	West Kamchatka	Ozerky Hatchery	Bolshaya River	422,000	1:1.3+2.2
R99-13	DM	unknown	Russia	Kamchatka	West Kamchatka	Ozerky Hatchery	Bolshaya River	95,000	1:1.3n
R99-15	DM	unknown	Russia	Kamchatka	East Kamchatka	Ketkino Hatchery	Avacha River	621,000	1:1.3+2.4
R99-18	TM	unknown	Russia	Sakhalin	Okhotsk Sea	Bereznykovsky Hatchery	Okhotsk Sea	22,546,100	1:1.4

[*1]DM, dry mark; TM, thermal mark
[*2]RBr, Regional band rings showing coding structure of thermal marks (Munk and Geiger 1998)

halin, Premorye, Amur River, and northern Russia (Magadan/Kamchatka/Anadyre).

Detection of otolith marks

Otoliths were collected from 206 juvenile chum salmon. The left sagittal otoliths were mounted on slide glasses using thermoplastic cement, and then ground to expose the primordia. If the left sagittal

Table 4. Contribution estimates of Asian stocks to juvenile chum salmon mixtures (n=191) caught in the Okhotsk Sea in the fall of 2000 using Asian baseline. Standard deviations (SD) and 90% confidence intervals (CI) are calculated from 1,000 bootstrap resamples and baseline.

Region	Estimate	SD	Lower CI	Upper CI
Japan	0.213	0.071	0.128	0.364
Amur River	0.219	0.054	0.111	0.289
Premorye	0.000	0.002	0.000	0.000
Sakhalin	0.253	0.084	0.087	0.356
Northern Russia	0.310	0.071	0.241	0.475

Table 5. Otolith marked chum salmon juveniles (age 0.0) caught in the Okhotsk Sea during the fall of 2000.

Sampling location			Sampling date	Fork length (mm)	Body weight (g)	Sex	Gonad weight (g)	Otolith marks		
Station #	Latitude (N)	Longitude (E)						RBr*	ID #	Facility released
7	51˚00´	148˚01´	Oct. 23	207	202.0	Male	0.22	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin
8	50˚01´	148˚00´	Oct. 24	214	100.4	Male	0.26	1:1.3n	R99-13	Ozerky Hatchery, west Kamchatka
8	50˚01´	148˚00´	Oct. 24	230	131.4	Male	0.19	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin
8	50˚01´	148˚00´	Oct. 24	208	106.2	Female	0.99	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin
9	49˚01´	150˚01´	Oct. 25	217	110.6	Male	0.31	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin
9	49˚01´	150˚01´	Oct. 25	215	116.1	Female	1.25	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin
9	49˚01´	150˚01´	Oct. 25	215	111.9	Male	0.41	1:1.4	R99-18	Bereznykovsky Hatchery, Sakhalin

*RBr, Regional band rings showing coding structure of thermal marks (Munk and Geiger 1998)

otoliths were not available, the right sagittal otoliths were used. Otolith microstructures were observed under a light microscope, and the microstructure patterns were compared to the thermal mark patterns of voucher specimens collected from hatcheries before releases (Table 3).

Results

Distribution of juvenile chum salmon

Juvenile chum salmon (age 0.0, n=206) were captured in seven sampling stations of the southwestern Okhotsk Sea (48-51˚N, 146-150˚E), but not in the other four stations located south of 47˚N (Fig. 1).

Genetic stock identification

The regional composition estimates of juvenile chum salmon (n=191) caught in the southwestern Okhotsk Sea were 21.3% Japan, 21.9% Amur River, 25.3% Sakhalin, and 31.0% northern Russia stocks (Table 4). The Premorye stock was absent in the mixture samples.

Otolith mark

Otolith marks were detected in seven juvenile chum salmon (3.4%) caught in the southwestern water (49-51˚N, 148-150˚E) on October 23-25 (Table 1). These marked fish originated from the Bereznykovsky Hatchery (n=6) in southern Sakhalin and the Ozerky Hatchery (n=1) in western Kamchatka. The fork length of the marked fish was in the range of 207-230 mm (Table 5).

Discussion

Urawa et al. (2001) estimated contributions of Asian stocks to a mixture of juvenile chum salmon caught in the Okhotsk Sea during October 1993. In the southern Okhotsk Sea, juvenile chum salmon were composed of 79% Japanese, 11% Amur, and 4% northern Russian stocks. Sakhalin and Premorye stocks were almost absent in the mixture. However, the present study suggested that Russian stocks including Sakhalin origin were dominant among juvenile chum salmon caught in the southwestern Okhotsk Sea during October 2000. The following survey conducted in the wide areas of the Okhotsk Sea during the fall of 2002 indicated that the stock composition of juvenile chum salmon was different among sampling stations (Urawa, unpublished information). This 2002 GSI results indicated that Russian stocks were dominant in the southwestern Okhotsk Sea, while Japanese stock was dominant in the southeastern waters.

This may be the first recovery record of Russian otolith marks from offshore of the Okhotsk Sea. Especially it is noteworthy that six marked fish were the Bereznykovsky Hatchery origin in Sakhalin. This hatchery released approximately 22 million thermal marked chum salmon fry in the spring of 2000 (Table 3). On the other hand, we found one dry marked fish released from the Ozerky Hatchery along the Bolshaya River in western Kamchatka, although only 95,000 chum salmon fry with the same mark (RBr 1:1.3n) were released from this hatchery.

In the spring of 2000, a total of 14 million thermally-marked chum salmon fry were released from the Chitose (Japan Sea coast), Shizunai and Shikiu (Pacific coast), Kunbetsu and Ichani hatcheries (Nemuro coast) in Hokkaido. However, Japanese marked fish were not detected among the present juvenile chum samples. The GSI analysis also suggested a low contribution of Japanese stocks. The low contribution of Japanese stock in juvenile chum salmon may be due to the sampling locations limited in the western waters.

Urawa et al. (2001) estimates that Japanese chum salmon juveniles stay in the Okhotsk Sea from summer until late autumn, overwinter in the western North Pacific Ocean, and then migrate into the Bering Sea by the following summer. We should continue the monitoring program for juvenile salmon in the Okhotsk Sea using stock identification and abundance estimate techniques to clarify the survival mechanisms of Asian chum salmon during the early ocean life.

Acknowledgements

We are grateful to the crew of the R/V *Torishima* for their cooperation to collect salmon samples.

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2000年秋にオホーツク海南西部で採集されたサケ幼魚の起源

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2000年10月にオホーツク海南西部で調査船とりしまにより採集されたサケ幼魚206個体の地理的起源を遺伝的系群識別法と耳石標識により推定した．アロザイム多型による遺伝的系群識別で推定された系群組成は，日本系21%，アムール系22%，サハリン系25%, 北ロシア系31%であった．7個体(3.4%)より耳石標識が検出されたが，これらはサハリンのBereznykovsky Hatchery (n=6)と西カムチャツカのOzerky Hatchery (n=1)より放流された幼魚であった．以上の結果は，2000年秋にオホーツク海南西部に分布したサケ幼魚はロシア系が大部分を占めていたことを示唆する．

Appendix. List of populations for Asian chum salmon baseline.

Population	Date of collection	Number of samples	Source
JAPAN			
Pacific Coast of Honshu			
Kido River	Nov. 7, 1994	80	Present study
Koizumi River	Nov. 21, 1996	80	Present study
Naruse River	Nov. 1995	80	Present study
Ohkawa River	Dec. 6, 1989	100	Winans et al. 1994
Katagishi River	Nov. 22, 1995	79	Present study
Hei River	Oct. 25, 1996	45	Present study
Tsugaruishi River	Dec. 7, 1989	100	Winans et al. 1994
Orikasa River	Oct 24, 1996	80	Present study
Japan Sea Coast of Honshu			
Tedori River	Nov. 8, 1994	40	Present study
Sho River	Nov. 14, 1994	80	Present study
Kurobe River	Oct. 31, 1996	80	Present study
Miomote River	Nov. 6, 1989	100	Winans et al. 1994
Uono River	Oct. 18, 1995	80	Present study
Gakko River	Dec. 8, 1994	40	Present study
Gakko River	Dec. 3, 1997	40	Present study
Gakko River	Nov. 8, 1989	39	Winans et al. 1994
Pacific Coast of Hokkaido			
Yurrapu River Early	Sep. 24, 1997	80	Present study
Yurrapu River Mid	Oct. 15, 1997	80	Present study
Yurrapu River Late	Nov. 17, 1997	80	Present study
Shikiu River	Oct. 1991	80	Present study
Shizunai River	Oct. 1991	80	Present study
Tokachi River	Sep. 27, 1990	80	Winans et al. 1994
Kushiro River	Oct. 19, 1989	100	Winans et al. 1994
Nemuro Coast			
Nishibetsu River	Oct. 17, 1989	100	Winans et al. 1994
Okhotsk Sea Coast			
Abashiri River	Oct. 19, 1998	80	Present study
Tokushibetsu River	Oct. 17, 1987	42	Winans et al. 1994
Yubetsu River	Nov. 1992	40	Present study
Shari River	Oct. 18, 1989	100	Winans et al. 1994
Japan Sea Coast of Hokkaido			
Chitose River	Oct. 16, 1989, 1990	180	Winans et al. 1994
Teshio River	Oct. 15, 1987	97	Winans et al. 1994
RUSSIA			
Amur River			
Amur River	1997	150	Wilmot et al. 1998
Premorye			
Ryzanovka River	1994	51	Wilmot et al. 1998
Avakumovka	1994	35	Wilmot et al. 1998
Narva	1994	18	Wilmot et al. 1998
Sakhalin Island			
Kalininka River	1994	49	Wilmot et al. 1998
Naiba River	1994, 1995	100	Wilmot et al. 1998
Udarnitsa	1994	98	Wilmot et al. 1998
Anadyr River			
Anadyr River	1991	104	Winans et al. 1994
Eastern Kamchatka			
Nerpichi Lake	July 19, 1991	40	Winans et al. 1994
Kamchatka River	Aug. 23, 1990; Aug. 2, 1991	120	Winans et al. 1994

Appendix. (continued).

Population	Date of collection	Number of samples	Source
Western Kamchatka			
Utka River	1991	79	Winans et al. 1994
Kikchik River	1991	40	Winans et al. 1994
Pymta River	July 29, 1990; 1991	159	Winans et al. 1994
Kol River	July 30, 1990	93	Winans et al. 1994
Hairusova River	July 3, 1990	154	Winans et al. 1994
Sea of Ohkotsk			
Tumani River	July 15, 1991	66	Winans et al. 1994
Ola River	Aug. 3, 1990; July 15, 1991	160	Winans et al. 1994