

# Analysis of otolith microchemistry of chum salmon, *Oncorhynchus keta*, collected in Otsuchi Bay, northeastern Japan

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Ontogenic change patterns in otolith Sr:Ca ratios were examined in the chum salmon, *Oncorhynchus keta* collected in Otsuchi Bay. Otolith Sr:Ca ratios of the salmon fluctuated strongly along the life history transect in accordance with the migration pattern, i.e. all specimens exhibited a typical anadromous pattern in the ratio. The chum salmon has low Sr:Ca ratios around the core region of otolith, whereas the distance (period) was extremely shorter than the other salmonids reported previously. Therefore, chum salmon might migrate to sea immediately after releasing from hatchery.

**Key words:** chum salmon, otolith, Sr:Ca ratios, migration

## INTRODUCTION

The chum salmon is one of seven species of North Pacific *Oncorhynchus* and has a typical anadromous life history. The young chum salmon generally go to sea immediately from the ground (Miller and Brannon 1982). After the migration in ocean waters for 1 to 5 years, they return to their natal river in fall, being of age 2 to 6 years (Nagasawa and Torisawa 1991). While 50 years of ocean research has greatly advanced our understanding of the distribution and many aspects of the biology of chum salmon, the behaviour and habitat use of individual salmon on the high seas remain poorly understood. Information on individual migratory histories would provide basic knowledge for both fish migration studies and fisheries management, allowing effective and sustainable use of the chum salmon resources.

Wave-length dispersive electron microprobe analysis of strontium (Sr) to calcium (Ca) ratios in otoliths has recently been focused as a method for distinguishing between freshwater and marine migratory phases in diadromous fishes.

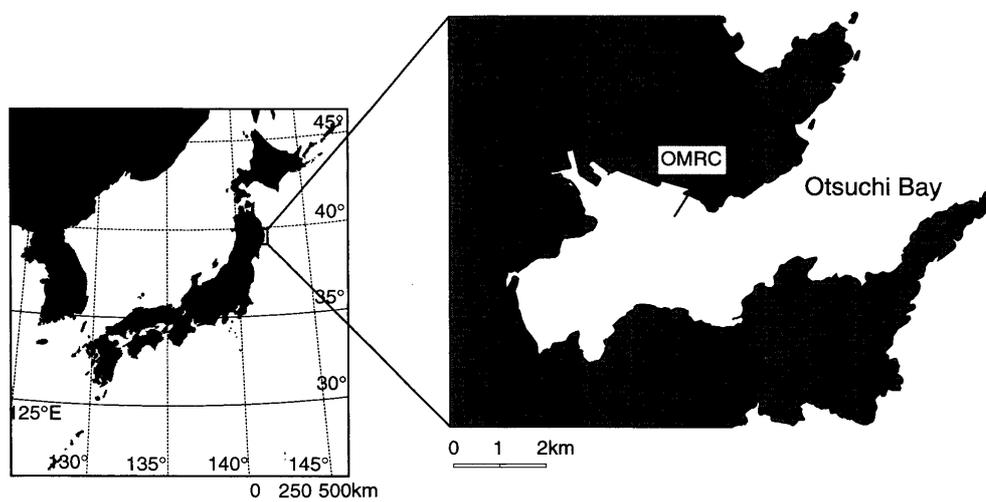
Accordingly, this technique might also be applied to solving the complicated problem of the migratory pattern in the chum salmon.

The objective of this study was to describe the ontogenic changes in otolith Sr:Ca ratios of *Oncorhynchus keta*, and to examine the usefulness of this technique in reconstructing the migratory history of the species.

## MATERIALS AND METHODS

*Oncorhynchus keta* was collected using set nets in Otsuchi Bay, Japan, on between August 29 and September 4, 2000 (Fig. 1). After measuring the total length (TL), body weight (BW) and gonadosomatic index (GSI) (Table 1), sagittal otoliths were extracted from each individual. Otoliths were then embedded in epoxy resin (Strues, Epofix), mounted on glass slides and ground to expose the core. After polishing with 6  $\mu\text{m}$  and 1  $\mu\text{m}$  diamond paste on a polishing wheel (Strues, Planopol-V), they were cleaned in an ultrasonic bath, rinsed with deionized water.

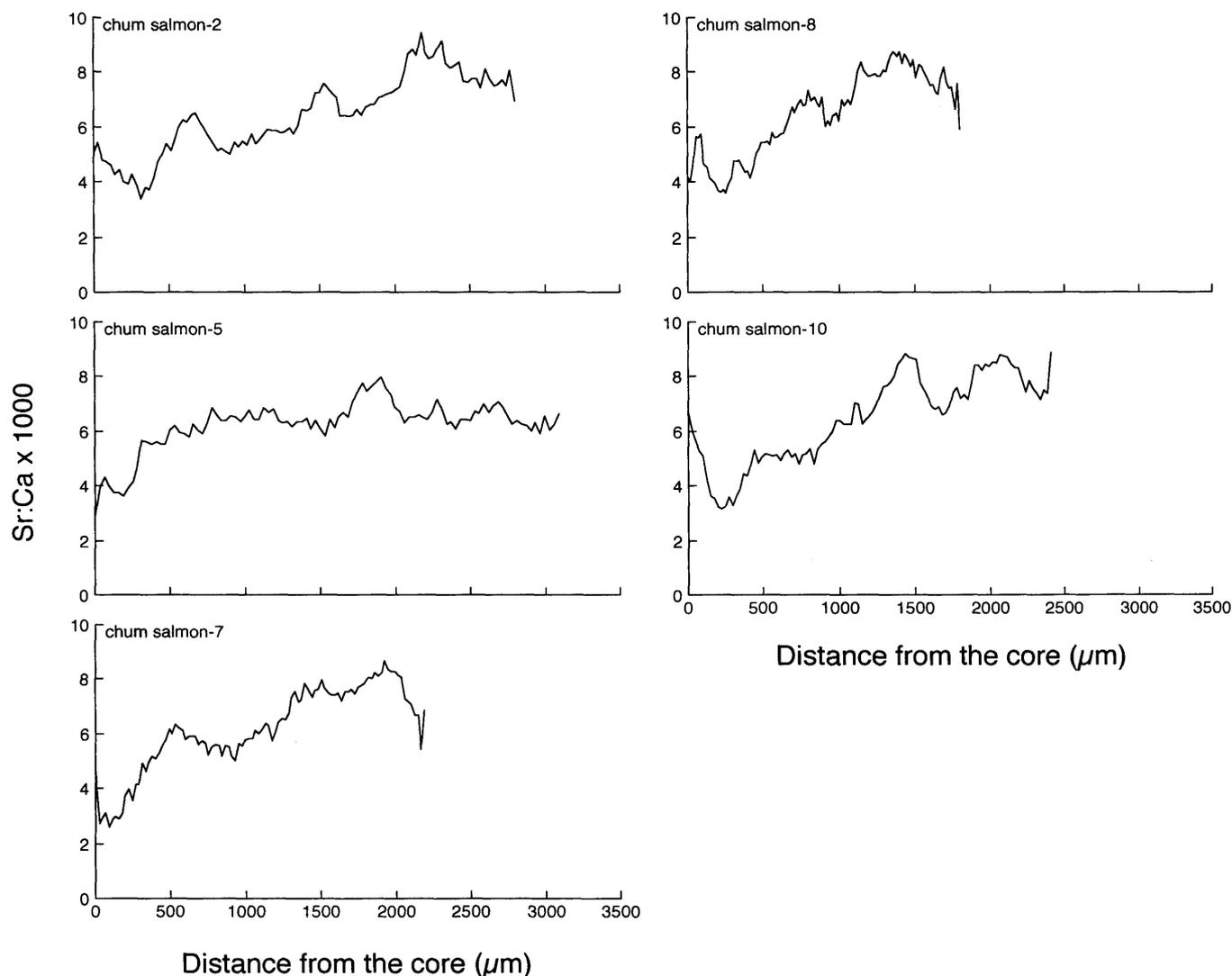
Electron microprobe analyses were carried out on the total of 5 specimens (Table 1). For electron microprobe



**Fig. 1.** Map showing the sampling location in Otsuchi Bay, northeastern Japan. OMRC indicates the location of Otsuchi Marine Research Center, Ocean Research Institute, The University of Tokyo.

**Table 1.** *Oncorhynchus keta*. Sampling date, sex, fork length, body weight and gonadosomatic index (GSI) used for microchemical analysis.

Fish number	Sampling date	Sex	Fork length (cm)	Body weight (g)	GSI (%)
Chum salmon-2	August 29, 2000	Female	62.4	2857	11.3
Chum salmon-5	August 30, 2000	Male	61.6	2725	6.5
Chum salmon-7	September 4, 2000	Male	72.4	3744	5.7
Chum salmon-8	September 4, 2000	Female	69.8	3061	14.8
Chum salmon-10	September 4, 2000	Female	62.9	2497	11.4

**Fig. 2.** *Oncorhynchus keta*. Profiles of otolith Sr:Ca ratios measured with a wavelength dispersive electron microprobe from the core to the edge. The number at the upper left indicates fish number.

analyses, all otoliths were Pt-Pd coated by a high vacuum evaporator. Sr and Ca concentrations were measured along the posterior axis from the otolith core using a wavelength dispersive X-ray electron microprobe (EPMA; JEOL JXA-8900R). Calcite ( $\text{CaCO}_3$ ) and strontianite ( $\text{SrCO}_3$ ) were used as standards. The accelerating voltage and beam current were 15 kV and  $1.2 \times 10^{-8}$  A, respectively. The electron beam was focused on a point of  $10 \mu\text{m}$  in diameter, with spacing measurements at  $10 \mu\text{m}$  intervals. Datum of each point represents the average of three measurements (each counting time: 4.0 sec).

## RESULTS

Migratory types of *Oncorhynchus keta* are shown in Fig. 2. In all specimens examined, the otolith Sr:Ca ratios in the core region, averaging  $4.6 \times 10^{-3}$  (range;  $3.5 \times 10^{-3}$ – $6.4 \times 10^{-3}$ ), and the ratios dropped slightly, averaging  $3.6 \times 10^{-3}$  (range;  $3.3 \times 10^{-3}$ – $3.8 \times 10^{-3}$ ), from the core region to the point at 200–400  $\mu\text{m}$ . The life history transects of Sr:Ca ratio were roughly divided into two patterns. The first pattern (chum salmon-2, 7, 8, 10) showed that the Sr:Ca ratios increased gradually toward the edge of otolith with two or three subsequent Sr:Ca ratios peaks ( $6.2 \times 10^{-3}$ – $8.3 \times 10^{-3}$ ).

The second pattern (chum salmon-5) was characterized by a temporary increase in Sr:Ca ratios, averaging  $6.2 \times 10^{-3}$ , from the outside of core region to edge of otolith, suggesting a long-term residence in a mild environmental variation in the ocean.

## DISCUSSION

This study confirmed that otolith Sr:Ca ratios in chum salmon reflected changes in ambient environmental conditions and could indicate habitat transitions. Otolith Sr:Ca ratios in the salmon changed abruptly from low to high values just outside of the core region of otolith, and thereafter increasing gradually or maintaining constantly high Sr:Ca ratios toward the edge. The abrupt increase in the ratio suggests that specimens had experienced the marine environment following downstream migration. Overall, the Sr:Ca ratio patterns observed in the chum salmon otoliths were consistent with those seen in other salmonids, i.e. *Salmo trutta*, *S. salar* and *Oncorhynchus mykiss* (Kalish, 1990), *O. nerka* (Rieman et al. 1994) and *O. masou* (Arai and Tsukamoto 1998). These considerations strongly suggested that otolith Sr:Ca ratio analysis was available to the estimation of the individual migratory history in chum salmon.

The chum salmon has low Sr:Ca ratios in the core region of otolith, whereas the distance (period) was extremely shorter than the other salmonids (Kalish 1990, Rieman et al. 1994, Arai and Tsukamoto 1998). It relates to the fact that chum salmon migrate to sea immediately after releasing from hatchery.

Change in otolith Sr:Ca ratios have been considered to relate to environmental factors such as water temperature (Radtke 1989, Radtke et al. 1990) and salinity (Arai and Tsukamoto 1998, Arai and Miyazaki 2001, Tsukamoto and Arai 2001). In the present study, the profile of the Sr:Ca in the chum salmon showed two or three subsequent peaks of the ratio. Recently, thermal environment study in chum salmon as indicated by data storage tags suggested that the salmon encountered the different temperature environment seasonally in the North Pacific and experienced temperature varied among individuals (Walker et al. 2000). Therefore, information of the seasonal temperature fluctuation experienced by individual fish during migration might be incorporated into the otolith. For higher accuracy, however, mark-recapture studies using micro data loggers will be needed to determine the precise correspondence between fish movement and Sr:Ca ratios in their otoliths.

This study is the first description of ontogenic changes in otolith Sr:Ca ratios in chum salmon, showing its potential for estimating migratory history. Tsukamoto et al. (1989) has previously estimated the migratory history of individual masu salmon by examining oxygen stable isotopic ratios ( $^{18}\text{O}/^{16}\text{O}$ ) in the otolith by mass spectrometry. The patterns in the otolith  $^{18}\text{O}/^{16}\text{O}$  ratios of masu salmon reflected ambient environmental salinity, relating to the upstream migration. However, comparing the analytical procedure between the two methods, the latter method was more complex than the nondestructive analysis performed in the present study. Furthermore, recent progress in otolith Sr:Ca ratio techniques using EPMA have demonstrated the considerable

potential of the method for reconstructing seasonal life history traits and ontogenic development of diadromous fishes: e.g. striped bass, *Morone saxatilis* (Secor et al. 1995), freshwater eel, *Anguilla japonica* (Tsukamoto and Arai 2001) and the Russian sturgeon, *Acipenser guldenstadti* (Arai and Miyazaki 2001). Therefore, the otolith Sr:Ca ratios technique by EPMA has a great potential as a convenient powerful tool to reconstruct the individual migratory history as well as a life history traits and ontogenic development.

## ACKNOWLEDGEMENT

This work was supported in part by Grant-in-Aid No. 13760138 from the Ministry of Education, Science, Sports, and Culture, Japan, Intelligent Cosmos Academic Foundation and Showa Shell Sekiyu Foundation for Promotion of Environmental Research.

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## 大槌湾で採集されたサケの耳石微量元素分析

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大槌湾の定置網で採集されたサケ *Oncorhynchus keta* 5個体の回遊履歴を耳石Sr/Ca比を用いて推定した。サケの耳石のSr/Ca比の低い部分と高い部分は、生息環境水中のSr/Ca比を反映し、それぞれ河川生活期間と海洋生活期間に対応しているものと考えられた。これより、本種の回遊履歴を耳石のSr/Ca比によって推定できると考えた。耳石中心部付近でみられたSr/Ca比の低い部分は、これまで報告された他のサケ科魚類に比べて著しく短かった。サケは放流後直ちに降海するものと推察された。

Received: 21 September 2001

Accepted: 7 December 2001