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Short Note

# Elemental composition in otoliths of surfperch, *Ditrema temmincki*

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**Abstract**—The elemental composition of the otolith was examined in both male and female surfperch, *Ditrema temmincki*. The determined concentrations of 22 elements were the same regardless of the fish's sex. K, Mg, and Na which are major elements in seawater, accumulations from seawater to otolith of those elements were quite smaller than other minor elements. This suggests that elemental discrimination might occur during the movement from blood plasma to endolymph after the branchial uptake from ambient water.

**Key words:** surfperch, *Ditrema temmincki*, otolith, elemental composition, *elemental discrimination*

## Introduction

Otoliths are paired calcified structures used for balance and/or hearing in all teleost fishes. Otolith composition is relatively pure compared to most biological and mineralogical structures, being dominated by calcium carbonate in a noncollagenous organic matrix. The chemical composition of fish otoliths is receiving increasing attention as a potential indicator or fingerprint of the chemical composition of fish habitats. Most studies of the elemental composition of fish otoliths have reported levels of elements, such as Ca and Sr, to reconstruct of migration histories in diadromous fishes (Kalish 1990, Secor et al. 1995, Arai et al. 1997, Arai and Tsukamoto 1998), while a few have reported concentrations of other elements (Campana 1999). The elemental composition of otoliths has been used to discriminate stocks and to examine habitat utilization by fish residing in waters differing in chemical compositions because of natural variability in ambient waters (Campana 1999) and pollution (Thorrold et al. 1997). Therefore, otolith elemental composition has a great potential as a biological tracer such as stock identification as well as an environmental tracer of fish habitats.

In order to accumulate basic information regarding otolith elemental composition, the otolith of *Ditrema temmincki*, a common embiotocid fish distributed widely along coastal regions, was investigated. The results formed the basis of a discussion regarding the metabolic process of elements in the otolith.

## Materials and Methods

*Ditrema temmincki* was collected using set nets in Otsuchi Bay, Japan, on March 2, 2001. After measuring the total length and determining the fish's sex, sagittal otoliths were extracted from each fish. A total of 10 otoliths in one side (5 male specimens, 5 female specimens) of the same growth stage (4 years old) were used for the present study. Otoliths were mechanically cleaned of attached tissue, and then washed in an ultrasonic bath and rinsed with deionized water. After cleaning, the otolith samples were dried at 80°C for 12 h.

In preparation for instrumental analysis, each whole otolith was weighed to the nearest 0.001 g (mean±SD: 0.035±0.007 g, range: 0.026 to 0.043 g) and placed in a PTFE (Teflon) vessel. Otoliths were then digested using microwaves to a transparent solution using a concentrated nitric acid. The resultant solutions were diluted with doubly deionized water and transferred to acid-washed sample tubes. Elemental concentrations were determined using inductively coupled plasma mass spectrometry (ICPMS) (Agilent 7500c). Internal standards were added to all samples, and the standards calibrated. The concentrations of all elements are reported as $\mu g\, g^{-1}$ on a dry weight basis. Limits of detection for each of the elements were ranged from 0.01 to 0.001, and all element concentrations in the otolith were above detection limits.

**Table 1.** Element concentrations (μg/g) in otoliths of surfperch collected from Otsuchi Bay, Japan.

| Elementy | *Ditrema temmincki* M mean±SD | range | *Ditrema temmincki* F mean±SD | range |
|---|---|---|---|---|
| Ag | 0.010±0.014 | 0.003–0.035 | 0.020±0.016 | 0.001–0.044 |
| Al | 0.17±0.07 | 0.086–0.257 | 0.22±0.07 | 0.155–0.315 |
| Ba | 3.3±1.1 | 2.3–5.2 | 2.8±0.07 | 0.155–0.316 |
| Cd | 0.017±0.015 | 0.010–0.044 | 0.008±0.005 | 0.004–0.016 |
| Co | 0.41±0.06 | 0.31–0.48 | 0.33±0.04 | 0.30–0.38 |
| Cr | 0.24±0.17 | 0.074–0.49 | 0.11±0.06 | 0.04–0.18 |
| Cs | 0.012±0.05 | nd–0.05 | 0.009±0.005 | nd–0.01 |
| Cu | 0.42±0.08 | 0.30–0.52 | 0.42±0.07 | 0.33–0.48 |
| Ga | 0.19±0.06 | 0.14–0.28 | 0.19±0.04 | 0.15–0.25 |
| K | 551±66 | 504–640 | 564±32 | 529–599 |
| Mg | 14.4±1.7 | 11.9–16.3 | 16.1±1.4 | 14.6–18.0 |
| Mn | 0.55±0.04 | 0.51–0.61 | 0.77±0.18 | 0.50–0.98 |
| Mo | 0.021±0.022 | 0.009–0.060 | 0.029±0.022 | 0.011–0.066 |
| Na | 2799±454 | 2177–3403 | 2671±140 | 2513–2869 |
| Pb | 0.029±0.015 | 0.015–0.049 | 0.013±0.005 | 0.005–0.018 |
| Rb | 0.047±0.020 | 0.031–0.081 | 0.047±0.007 | 0.036–0.055 |
| Sb | 0.011±0.016 | nd–0.04 | 0.012±0.006 | nd–0.02 |
| Se | 7.4±1.2 | 7.0–10.0 | 9.1±1.5 | 7.0–10.0 |
| Sr | 4130±695 | 3000–4907 | 3631±242 | 3291–3966 |
| Ti | 0.006±0.014 | nd–0.032 | 0.004±0.004 | nd–0.010 |
| V | 0.013±0.021 | 0.002–0.051 | 0.011±0.006 | 0.001–0.016 |
| Zn | 0.090±0.071 | nd–0.185 | 0.41±0.30 | 0.057–0.77 |

## Results and Discussion

The present study showed for the first time the concentrations of various elements in surfperch, *Ditrema temmincki* otoliths (Table 1). No significant difference was apparent between the sex regarding all elements (Ag, Al, Ba, Cd, Co, Cr, Cs, Cu, Ga, K, Mg, Mn, Mo, Na, Pb, Rb, Sb, Se, Sr, Ti, V, Zn) (Mann-Whitney U-test, $P>0.1$). Accordingly, the elemental composition of the surfperch otolith might have a potential use as an indicator or fingerprint of the chemical composition of fish habitats regardless of the fish's sex.

It is noteworthy that significant differences in accumulations from seawater to otolith are found in each element (Fig. 1). K, Mg, and Na which are major elements (>100 mg/kg) in sea water, however uptake from sea water into the otolith of those elements is lower than other minor elements (<100 mg/kg) in sea water (Fig. 1). This suggests that elemental discrimination might occur during the movement from ambient water to otolith. The basic pathway of the bulk of inorganic elements into the otolith is from the water into the blood plasma via the gills or intestine, then into the endolymph, and finally into the crystallizing otolith. Water passing over the gills (branchial uptake) is the primary source of most elements in freshwater fish, while the continual drinking of marine fish is the main source of water-borne elements for assimilation via the intestine (Olsson et al. 1998). A small but unknown proportion of elements is un-

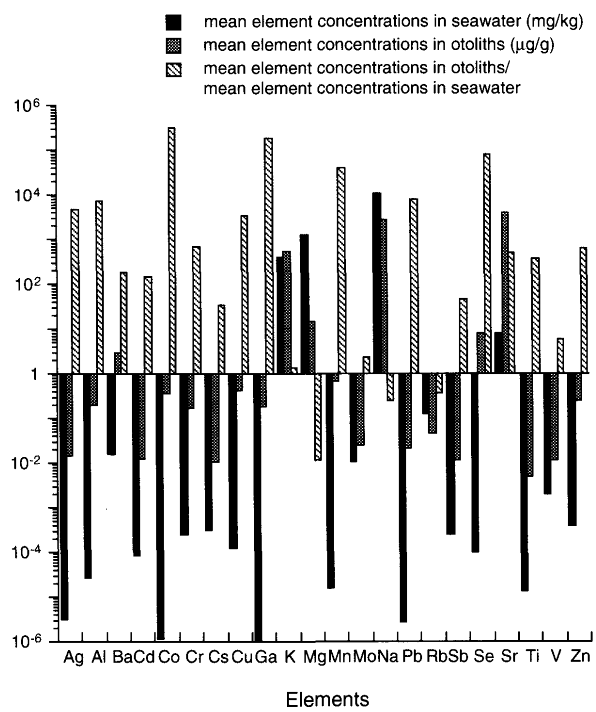


**Fig. 1.** *Ditrema temmincki.* Mean elemental concentrations in seawater (Nozaki 1992), elemental composition in otoliths of surfperch and concentration factors from seawater to otolith of surfperch in each element.

doubtedly assimilated from food sources. Farrel and Campana (1996) suggested that some of the Sr in the diet was incorporated into the otolith. However, other experiments suggested that otolith uptake of elements from food was minimal (Hoff and Fuiman 1995). Therefore, the majority of the inorganic otolith elements are probably derived from ambient water. Campana (1999) suggested that biggest barriers to elemental uptake occurred at the intestine-water interface in marine fish, where osmoregulation controlled the movement of water-borne ions into the fish, while minor elements such as Ba, Mn, Pb, Sr, and Zn were consistent with an environmental effect. These considerations all lead to the conclusion that in the otolith marked elemental discriminations regarding K, Mg, and Na are due to strict osmoregulatory control in sea water, while other minor elements reflect the elemental composition of the ambient water in fish habitat.

Teleost otoliths consist mainly of calcium carbonate in the aragonite form, and contain various elements that record environmental conditions experienced by fishes. The 2+ elements which have larger ionic radius sizes than does calcium are easily incorporated into aragonite crystal, and especially alkaline earth metal which has similar properties with Ca in a chemical reaction with the same 2+ valence. The ionic radii of alkaline earth metal are Mg (0.65 Å)<Ca (0.99 Å)<Sr (1.13 Å)<Ba (1.35 Å). The mean concentrations of elements in seawater are Mg (10780 mg/kg)>Ca (412 mg/kg)>Sr (7.8 mg/kg)>Ba (0.02 mgl/kg) (Nozaki 1992). In the present study, the uptake of Mg from seawater to otolith is lowest level of the other in spite of the highest concentration in seawater of the other, while Sr concentration was detected at higher levels than other elements. These data suggest that Sr can be easily substituted for Ca in the process of incorporation into aragonitic otoliths since Sr has a lager ionic radius than does Ca and a similar ionic radius than other elements with Ca, and elemental discrimination might occur due not only to biological, physiological and geochemical factors but also due to inorganic factors. Further studies are required on the element metabolism processes in otoliths in order to understand the minute changes in the elemental composition of otoliths.

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