Using Otolith Sr Concentrations to Monitor Marine Migrations in Rainbow trout (*Oncorhynchus mykiss*) from Shoal Harbour, Newfoundland

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USING OTOLITH SR CONCENTRATIONS TO MONITOR MARINE MIGRATIONS IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) FROM SHOAL HARBOUR, NEWFOUNDLAND

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ABSTRACT

Veinott, G. 2011. Using otolith Sr concentrations to monitor marine migrations in rainbow trout (*Oncorhynchus mykiss*) from Shoal Harbour, Newfoundland. Can. Manuscr. Rep. Fish. Aquat. Sci. 2950: iii + 11 p.

Twelve rainbow trout were provided to DFO from anglers in the Shoal Harbour area. Eleven of the 12 specimens were female and most were sexually immature. Ages ranged from 3 to 7 years with river ages of 1-4 years and sea ages of 1- 4 years. Only the oldest specimen had a spawning mark on its scales.

Chemical analyses (strontium concentrations) of the otoliths revealed that all specimens migrated from freshwater to the estuary or the sea. Time spent in the estuary, which is a mix of fresh and sea water, varied among individuals as did the time spent in full salinity sea water. Growth interpreted as “sea age” based on the scales often turned out to be estuarine growth based on the chemical analyses. There was no evidence that any of the specimens returned to fresh water to spawn or overwinter. This suggests that once out of the river the rainbow trout take up residency in the estuary or open ocean often for several years.

RÉSUMÉ

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Des pêcheurs de la région de Shoal Harbour ont fourni à Pêches et Océans Canada (MPO) 12 truites arc-en-ciel, dont 11 femelles, presque toutes sexuellement immatures. Les âges variaient de trois à sept ans, avec des phases de croissance en eau douce de un à quatre ans et des séjours en mer de un à quatre ans. Des marques de frai étaient visibles sur les écailles du spécimen le plus âgé seulement.

D’après les analyses chimiques (concentrations de strontium) des otolithes, tous les spécimens avaient effectué la migration de l’eau douce vers l’estuaire ou la mer. La durée du séjour dans l’estuaire, où l’eau douce se mélange à l’eau salée, ainsi que la durée du séjour en milieu de salinité maximale variaient d’un individu à l’autre. Les analyses chimiques ont démontré que ce qu’on considérait comme une « phase de croissance en mer », d’après la lecture des écailles, était en fait une croissance en milieu estuarien dans la plupart des cas. Rien n’indiquait qu’un des spécimens était revenu en eau douce pour y frayer ou y passer l’hiver, ce qui laisse entendre que la truite arc-en-ciel, une fois qu’elle a quitté la rivière, passe plusieurs années dans l’estuaire ou en mer.

INTRODUCTION

Otoliths or earstones are part of the sensory system of most fish (Campana 1999) including rainbow trout. They grow incrementally which means new layers of material are added periodically. When viewed in cross-section the growth layers appear as opaque (dark) and translucent (light) bands (Fig. 1). The bands are often related to periods of rapid and slow growth: for example, summer-winter growth, freshwater-marine growth, migrations, or a combination of these types of events.

The otolith is composed primarily of calcium (Ca) carbonate. However, small quantities of impurities become incorporated into the otolith during growth (Campana 1999). One such impurity is strontium (Sr) which is incorporated into the otolith in proportion to the Sr:Ca ratio of the ambient environment (i.e. water) (Campana 1999; Bath et al 2000; Kraus and Secor 2004; Zimmerman 2005). In natural waters the Sr:Ca ratio can vary considerably (Kraus and Secor 2004), but often freshwater has a much lower Sr:Ca ratio than marine waters, with estuarine waters somewhere in between (Secor and Rooker 2000). Therefore, the Sr concentration in the otolith is a function of the salinity of the water, and the Sr "tag" can be used to track the movement of fish between fresh, estuarine, and marine waters (Elsdon et al. 2008; Zimmerman 2005).

Elsdon et al. (2008) discusses in detail the assumptions and limitations of using chemical tags in otoliths to describe movements of fish. Basically two conditions must be met: first, there must be a difference in the Sr:Ca ratio in the different environments that the fish might encounter. For example, if a fish lives in a freshwater stream, migrates to an estuarine environment, then eventually moves into full salinity sea water, the Sr:Ca ratio in each of these environments must be different from each other. Second, the fish must remain in a particular environment long enough for the chemical tag to be incorporated into the otolith, and in a high enough concentration to be detected. If these conditions are met then a natural Sr tag can be used to distinguish freshwater, estuarine, and marine growth in the otolith.

In Shoal Harbour River on the east coast of Newfoundland (Fig. 2) there is a naturally reproducing population of rainbow trout. Rainbow trout are not native to Newfoundland and are believed to have been introduced on the Avalon Peninsula around 1887 (Scott and Crossman 1964). Although rainbow trout have been found throughout most of Newfoundland (Porter 2000) few established populations have been reported on the east coast of the island.

The Shoal Harbour River rainbow trout population supports a local sport fishery. However, nothing is known about their marine migrations or the extent to which rainbow trout use the estuarine environment. The purpose of this study therefore, was to use Sr in the otoliths of rainbow trout from Shoal Harbour to study the frequency and duration of their marine migrations.

METHODOLOGY

Twelve rainbow trout from the Shoal Harbour area were provided by anglers to the Department of Fisheries and Oceans (DFO) staff in 2009. No information on the time when the fish were angled or the specific location where they were caught was provided. Lengths and weights were recorded in-house by DFO staff and scale ages were determined by experienced DFO scale readers using the techniques described in ICES (1984). Otoliths were removed, cleaned and stored in individual plastic vials until they were needed for sectioning.

Otoliths were sectioned following the method of Jenke (2002). To determine the Sr concentration in the otoliths LA-ICP-MS (Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry) was used. In LA-ICP-MS, a laser is fired at the exposed surface of the sectioned otolith and the material that is removed from the otolith by the laser is swept into the plasma of the ICP-MS by a stream of argon. In this study the otoliths were ablated using a GEOLAS 193 nm excimer laser attached to a Finnigan ELEMENT XR high resolution double focusing magnetic sector ICP-MS. The laser beam had a 40 µm diameter, was fired at a rate of 10Hz, and had an output energy of approximately 5 J•cm^{-2}. Sr intensities were reduced using Memorial University's in-house CONVERT and LAMTRACE programs (Longerich et al. 1996) and normalized to the National Institute of Standards and Testing (NIST) standard reference material 612; trace element spiked glass bead. LAMTRACE compares the average Sr/Ca ratio in the NIST standard and the unknowns to the known Sr concentration in the standard to produce a Sr concentration in the unknowns. Ca was used as an internal standard to correct for ablation yield and instrument drift.

To produce life history Sr profiles the laser burned a track along the surface of the section from the otolith core to the growing edge (Fig. 1). The core of the otolith represents material produced when the fish was very young whereas the growing edge of the otolith was deposited just prior to the fish's death. Material from the otolith therefore, is continually fed into the ICP-MS and a profile of the Sr concentrations in the otolith from early in the fish's life until its death is produced (e.g., Fig. 3).

RESULTS AND DISCUSSION

The biological characteristics of the 12 trout sampled from Shoal Hr. are given in Table 1. It can be seen from the data in Table 1 that all but one specimen was female and most were sexually immature. Based on the scales, total age ranged from 3 to 7 years with 1-4 years of freshwater growth (river age) and 1-4 years of marine growth (sea age). Only the oldest specimen (FOSHR003) had any spawning marks on its scales.

Based on the Sr profiles from the otoliths, several life history or migration patterns were identified. The first is where an individual leaves the fresh water and migrates straight to full salinity sea water. An example of this type of migration is shown in the otolith from specimen FOSHR001 (Fig. 3). The freshwater growth produced a Sr concentration of about 500 ppm (parts per million) and then at about 650 microns from the core the Sr concentration rises sharply to a value of over 3500 ppm. Otolith Sr concentrations in the 3000-4000 ppm range generally only occur in full salinity sea water.

There is no age data for this specimen but based on its length it would be expected to be 3 or 4 years old. Assuming the growth on the otolith is somewhat consistent then it appears as if the fish spent half its life in freshwater and the other half in more saline waters. However, it is interesting to note that near the end of the profile (Fig. 3) at approximately 1000 microns from the core, the Sr concentration declines to about 2500 ppm. This is an indication of a move out of the full salinity of the marine environment into a mix of freshwater and salt water which typically occurs in an estuary. The profile also suggests this fish was in the estuary for some time prior to it being angled given that approximately 200 microns of otolith growth has an estuarine signature.

Similar Sr profiles to Fig. 3 are found in FOSHR002, 003, 006, 008, 010, and 012 (Fig. 4). In these cases river and sea ages are available. The differences in the profiles are caused by the timing of the move to the marine environment and the duration of the marine phase. The scales from specimens 002 and 006 suggest two years of sea growth in each case. However, the Sr profile for specimen 006 suggests a very short stay in marine waters (3500 ppm Sr) and the remainder of time in the estuary (1500-2000 ppm Sr). In contrast, specimen 002 appears to have spent all its marine time in full salinity sea water.

Specimen 003 had a scale sea age of 4 years. This is supported by the Sr profile which shows a rapid rise to over 3000 ppm Sr and then remaining somewhat level with small oscillations in the Sr concentrations. Interestingly at the end of the profile, between 1200 and 1300 microns, the Sr concentration is in steady decline. This decline seems to be mirroring the initial rise and could be an indication that the specimen was acclimating for a return to fully fresh water. This was the only specimen that showed a spawning mark on its scales and rainbow trout must return to freshwater to spawn. However, at no time does the Sr concentration return to the initial freshwater value.

Without detailed information on the time and location when these specimens were angled it is difficult to know if freshwater Sr concentrations were to be expected in the otolith profiles. In anadromous Arctic char (*Salvelinu* alpinus) Sr concentrations have been shown to decrease just as rapidly as they increase when moving between salinity regimes (Radtke et al. 1998; Halden, et al. 2000). Although the Sr concentrations in the Radtke et al. (1998) and Halden et al. (2000) studies declined when the fish entered freshwater they did not completely return to their initial freshwater values.

There are two possible explanations for Sr not reaching an initial freshwater value although the fish has resided in freshwater. One is that the duration of the freshwater residency is short and the otolith therefore does not have time to acquire a “true” freshwater value. Second the duration of the freshwater residency is long but growth has slowed or stopped and therefore the resolution of the laser is not fine enough to sample freshwater material only. Therefore, some of the declines or the oscillations in Sr concentrations in this study’s otoliths may be indicative of movement between salinity regimes and not necessarily residency in one environment.

In contrast to Figs. 2 and 3 a different migration pattern is found in the profiles from specimens 004, 005, 007, and 009 (Fig. 5). In these cases there is either estuarine residency (1500-2000 ppm Sr, specimens 005, 007) or a less abrupt transition between fresh and marine Sr signals. All diadromous fish must acclimate to different salinities before residency can be taken up in a new environment. In several of these examples the time spent in the estuary is considerable compared to some of the earlier examples (e.g., Fig. 2) where the rise in Sr concentrations was very steep. In specimen 009 there is a period of estuarine residency before the sudden increase to over 3000 ppm Sr. The maximum Sr concentration recorded in specimen 004 is over 5000 ppm which is unusually high even for marine samples. This may have been caused by an analytical error.

An examination of the laser track on specimen FOSHR-011 found that the laser did not run perpendicular to the growth lines. This meant that the data were not representative of the potentially different growth environments. Therefore specimen FOSHR-011 was not discussed.

Overall the otoliths revealed that all specimens migrated from freshwater to the estuary or the sea. Time spent in the estuary varied among individuals as did the time spent in full salinity sea water. Growth interpreted as “sea age” based on the scales often turned out to be estuarine growth based on the chemical analyses. There was no evidence that any of the specimens returned to fresh water for long periods of time. This suggests that once out of the river the rainbow trout take up residency in the estuary or open ocean often for several years.

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Table 1. Biological Characteristics of Sampled Rainbow Trout from Shoal Harbour River.

Specimen Number	Species	Collection Location	Gear	Fork Length (cm)	Whole Weight (g)	Sex	Maturity	Total Age	River Age	Sea Age
FOSHR 001	Rainbow trout	Shoal Harbour River	Angled	27.7	282	F	Mature (ripe)	no age		
FOSHR 002	Rainbow trout	Shoal Harbour River	Angled	24.3	194	M	Mature (ripe)	4	2	2
FOSHR 003	Rainbow trout	Shoal Harbour River	Angled	58	2546	F	Mature (ripe)	7	3	4
FOSHR 004	Rainbow trout	Shoal Harbour River	Angled	36.4	632	F	Immature	5	2	3
FOSHR 005	Rainbow trout	Shoal Harbour River	Angled	23	124	F	Immature	3	2	1
FOSHR 006	Rainbow trout	Shoal Harbour River	Angled	32.3	445	F	Immature	5	3	2
FOSHR 007	Rainbow trout	Shoal Harbour River	Angled	32.5	382	F	Mature (ripe)	5	4	1
FOSHR 008	Rainbow trout	Shoal Harbour River	Angled	28.8	291	F	Immature	3+	1+	2
FOSHR 009	Rainbow trout	Shoal Harbour River	Angled	30	346	F	Immature	4	2	2
FOSHR 010	Rainbow trout	Shoal Harbour River	Angled	26.5	219	F	Immature	4	3	1
FOSHR 011	Rainbow trout	Shoal Harbour River	Angled	31.5	439	F	Immature	4	2	2
FOSHR 012	Rainbow trout	Shoal Harbour River	Angled	30	334	F	Immature	4	2	2

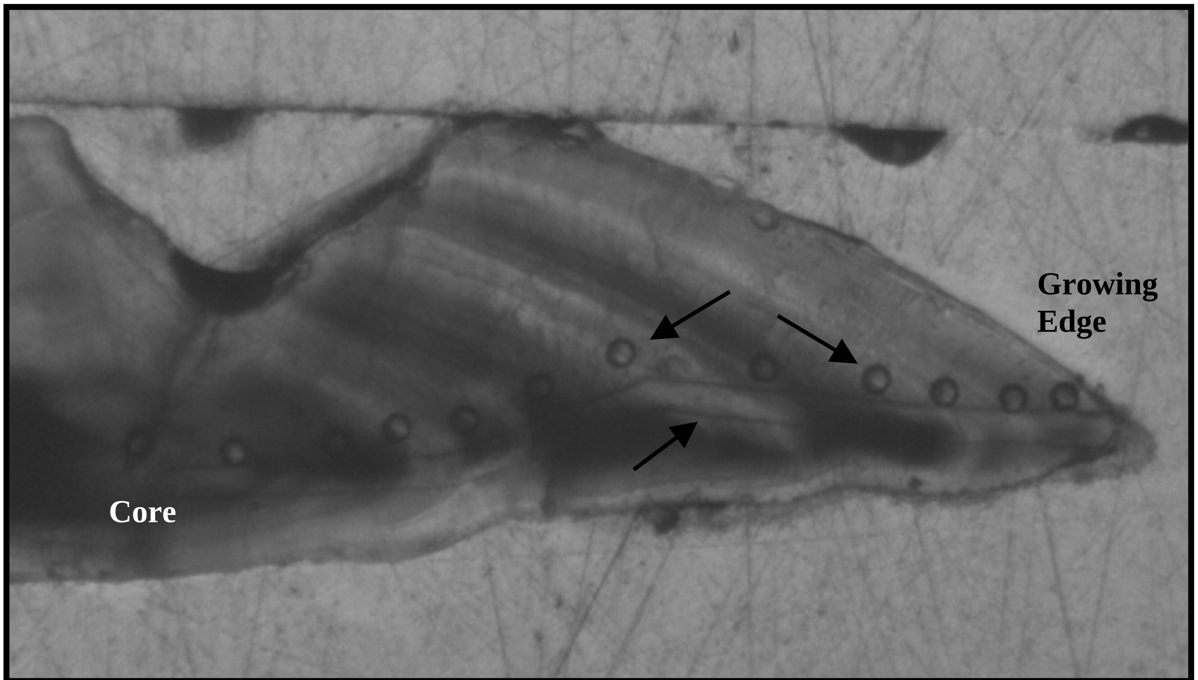

Figure 1. Micrograph of an otolith section. The light (translucent) and dark (opaque) bands are growth zones. Arrows indicate laser burns (circles) and a laser track (line) (See Methods section).

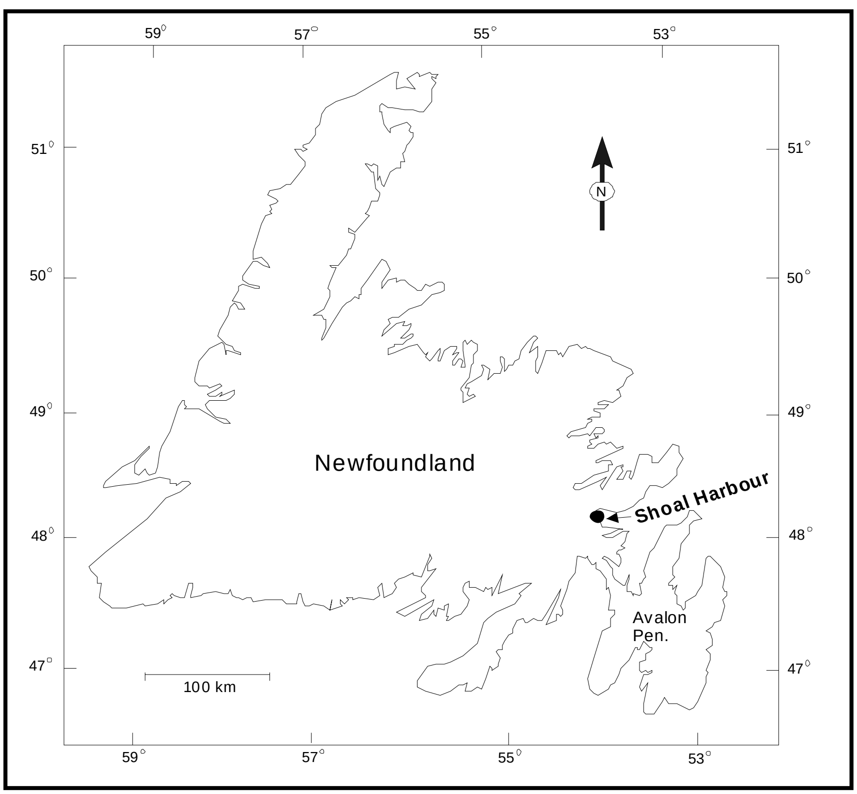

Figure 2. Map of the island of Newfoundland showing location of Shoal Harbour.

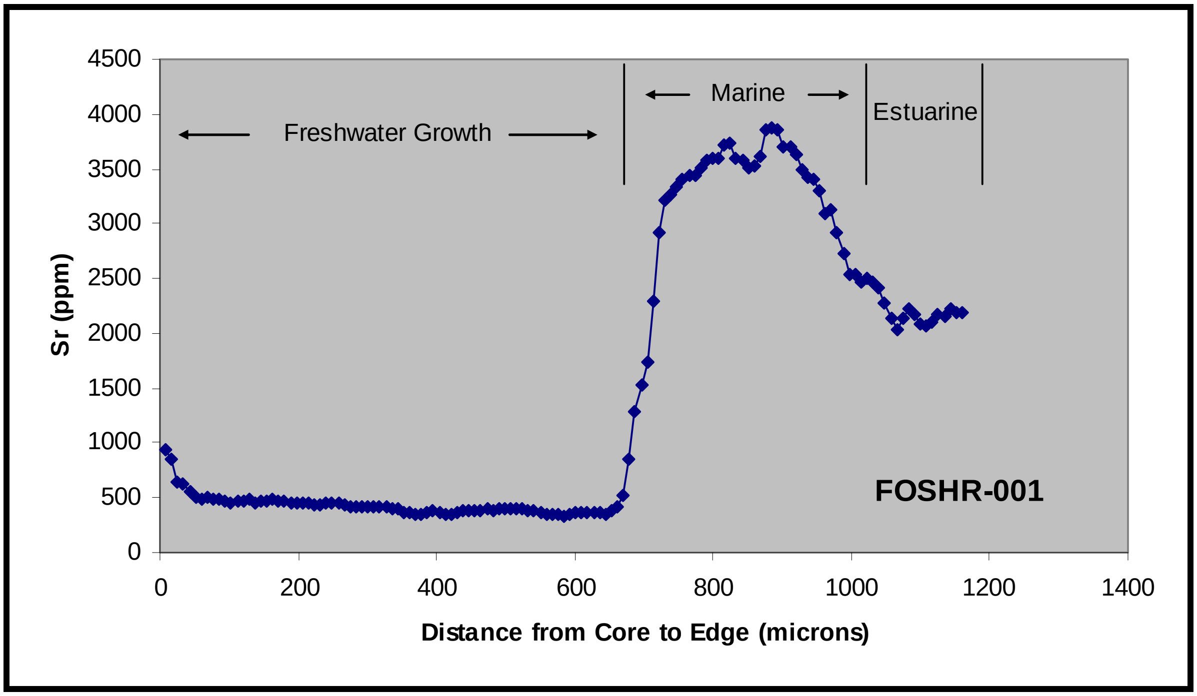

Figure 3. Strontium (Sr) profile of rainbow trout FOSHR-001 from Shoal Harbour. The growth environment corresponding to different Sr concentrations is shown.

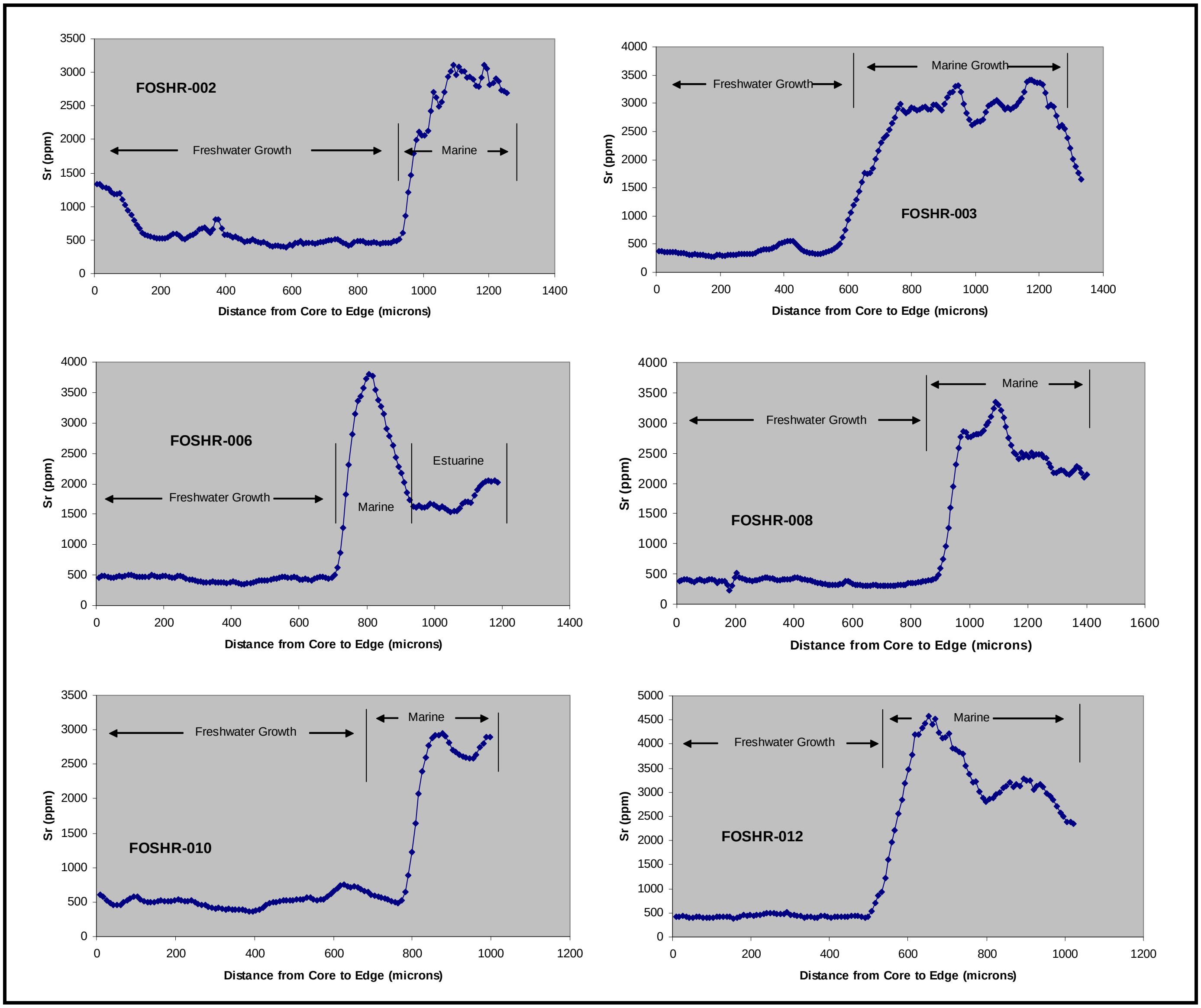

Figure 4. Strontium (Sr) profiles of rainbow trout from Shoal Harbour. Low Sr concentrations (~500 ppm) correspond to freshwater growth. Higher Sr concentrations correspond to marine and estuarine growth.

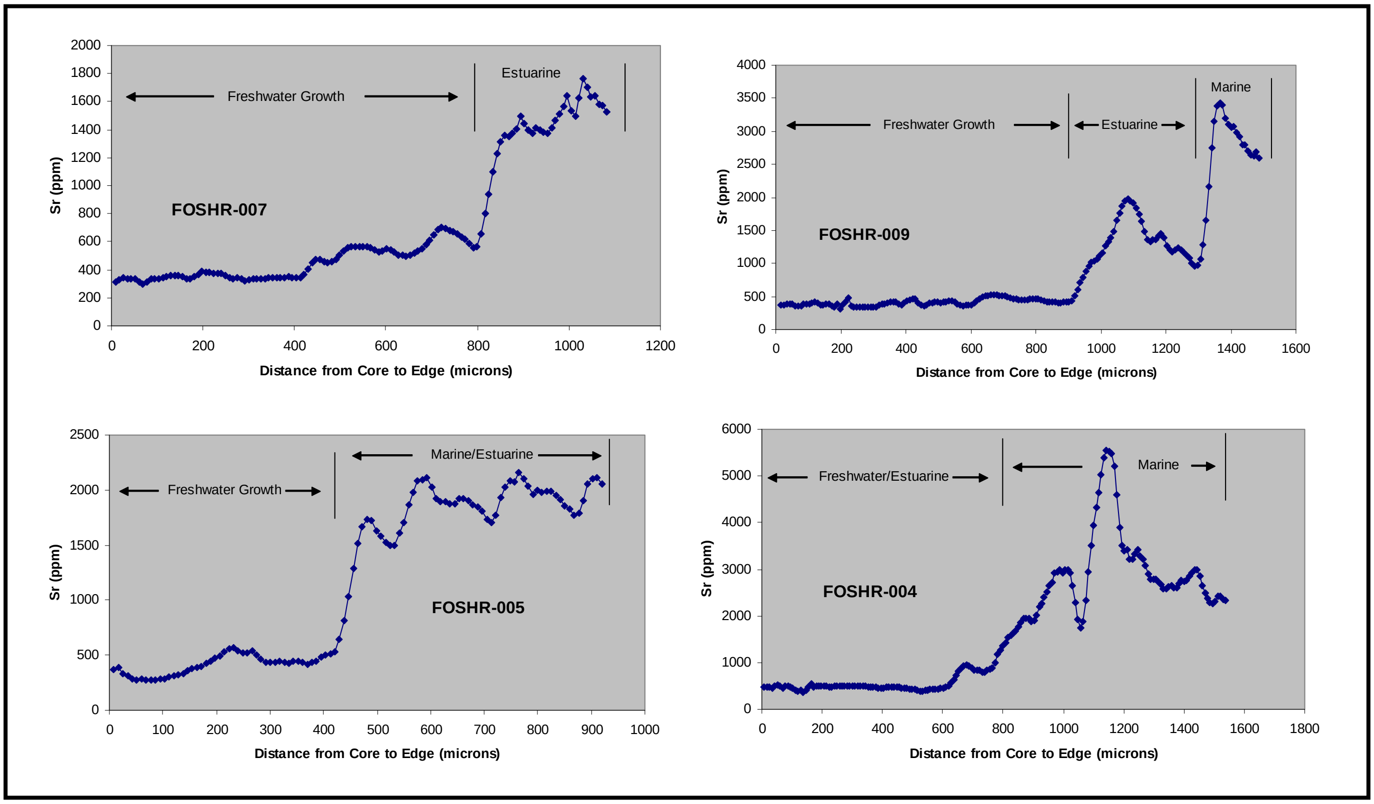

Figure 5. Strontium (Sr) profiles of rainbow trout from Shoal Harbour. Low Sr concentrations (~500 ppm) correspond to freshwater growth. Higher Sr concentrations correspond to marine and estuarine growth