行政院國家科學委員會專題研究計畫　期中進度報告

魚類耳石微化學的研究與應用(2/3)

計畫類別：個別型計畫
計畫編號：NSC92-2313-B-002-057-
執行期間：92年08月01日至93年07月31日
執行單位：國立臺灣大學漁業科學研究所

計畫主持人：曾萬年

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報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 93年5月31日

一、中文摘要

本研究以耳石之鍶鈣比 (Sr: Ca ratios) 來探討大眼海鰱 *Megalops cyprinoides* 之洄游環境史及洄游行為。大眼海鰱為海洋魚類，成魚在海水中產卵。孵化後之柳葉形仔稚魚隨著海流漂送至河口域成長。但變態為幼魚之後，它們的棲地選擇似乎非常複雜，從河口、紅樹林到溪流都能發現它們的蹤跡。而利用耳石鍶鈣比正是研究魚類洄游現象的最佳工具。首先，以實驗來證明大眼海鰱耳石鍶鈣比和環境中水體鹽度的關係。結果發現大眼海鰱柳葉魚飼養於 0‰ 的鹽度下，其耳石鍶鈣比會從海水柳葉魚階段的 8‰ 降至 4‰ 以下，飼養於 10‰ 及 35‰ 的鹽度下耳石鍶鈣比則維持在 4-8‰ 之間。根據此實驗數據進行野生大眼海鰱洄游行為之調查時發現大眼海鰱在幼魚階段可在淡水或海水中成長, 有些個體則會在淡海水間移動,但成魚最終都會回到海水中產卵。此研究結果顯示：(1)、耳石鍶鈣比可用於探討大眼海鰱洄游環境史。(2)、大眼海鰱在幼魚階段的洄游行為及棲地選擇是隨機性的。

關鍵詞：耳石、大眼海鰱、柳葉魚、鍶鈣比

二、Abstract

Pacific tarpon *Megalops cyprinoides* are widely distributed in the tropical and subtropical areas of Indo-Pacific Ocean. They spawn in the coastal waters, and then their larvae drift with currents to estuarine nursery ground approximately 25 -30 days post-hatching. Young Pacific tarpons were found in variety of environment, such as stream, estuary, inner bays, and mangrove. The strontium (Sr) concentration is approximately 100 fold higher in sea water than in freshwater, and Sr/Ca ratios in fish otolith were positively correlated to ambient salinity; thus the ratio was widely used to study the fish migration between seawater and freshwater. To study the migratory environmental history of Pacific tarpon, Sr/Ca ratios in otoliths of the fish, including leptocephalus, young and adult, collected from Gongshytyan Creek and Tadu Creek estuary were examined by Electron Probe Microanalyzer (EPMA). Sr/Ca ratios in otoliths of the fish at leptocephalus stage were higher and similar among individuals. But the patterns of Sr/Ca ratios beyond juvenile stage were very complicated, indicating that the fish after metamorphosis from leptocephalus may migrate among different environment. If the fish stayed in the estuarine and marine environment Sr/Ca ratios in otolith were greater than 4‰, but less than 4‰ if they moved to freshwater. These demonstrated that the migratory environmental history of the tarpon can be retrieved from the otolith Sr/Ca ratios and the habitat selection of the fish beyond juvenile stage is facultative.

KEYWORDS: Otolith, Pacific tarpon, Leptocephalus, Sr/Ca ratio

三、緣由與目的

耳石為硬骨魚類內耳迷路中的碳酸鈣結晶，以每日一輪的速度沉積(Campana and Neilson, 1985, Jones, 1986)。魚類耳石微化學分析是重建魚類生活史的重要方法之一，透

過耳石中微量元素的分析可探知魚類過去曾經生活過的環境，特別是以耳石鍶鈣比應用於洄游性魚類生活環境轉變之研究 (Radtke and Dean, 1982; Neilson et al., 1985, Victor, 1986, Chambers and Leggett, 1987; Tzeng and Tsai, 1994, Tzeng, 1995; Cheng and Tzeng, 1996, Shen et al., 1998, Jessop et al., 2002).。大眼海鰱雖不是重要的經濟魚類，但在演化上卻和鰻魚同屬海鰱首目(Superorder Elopomorpha)，都具有柳葉形仔稚魚階段 (Hulet and Robins, 1989)。是研究柳葉魚發育、生活史轉變的最佳材料。大眼海鰱雖為海洋魚類，但幼魚階段常在淡水溪流中被發現，此種洄游行為是否有一定的準則或者只是機能性的為補食獵物而進出淡水則不清楚。透過耳石微化學分析將有助於重建大眼海鰱洄游環境史及洄游行為模式之分析。因此本研究之目的包括： (1)以實驗探討大眼海鰱耳石鍶鈣比和環境水體中鹽度的關係 (2)分析野生大眼海鰱耳石之鍶鈣比以重建其洄游環境史。(3) 判斷大眼海鰱的洄游行為及模式。

四、材料和方法

大眼海鰱標本採集於 1998 年至 2004 年間，包括在北部公司田溪 (Gongshytyan Creek) 河口以定置網捕捉剛加入之大眼海鰱柳葉魚及在中部大肚溪 (Tadu Creek) 下游(CT)、中游 (TD)及沿海以刺網捕捉大眼海鰱幼魚及成魚 (Fig. 1)。 捕獲之大眼海鰱經測量尾叉長及體重後，將其矢狀石(sagitta)取出。耳石經包埋、拋光及鍍碳之後，以電子微探儀 (EPMA，型號 A JEOL JXA-8900) 分析耳石核心至邊緣鍶及鈣離子濃度。定量分析之電子束條件為：加速電壓 15 keV、電流 5 nA、電子束面積 $5 \times 4 m^2$ 。所獲得之資料以碳酸鈣 ($CaCO_3$, NMNH 136321) 及碳酸鍶 ($SrCO_3$, NMNH R10065) 為標準物，經 ZAF 法計算氧離子組成來校正。在北部公司田溪捕獲之大眼海鰱柳葉魚以 OTC 標誌後飼養於 3 種不同鹽度之水中(0‰、10‰、35‰)及 2 種溫度(20℃、30℃)，飼養兩星期後取出耳石做鍶鈣比分析。

五、結果與討論

在北部公司田溪所捕獲的大眼海鰱柳葉魚，經 OTC 標誌後，飼養於 3 種不同鹽度 (0‰、10‰、35‰)及 2 種溫度(20℃、30℃) 之水中，飼養兩星期後取出耳石做鍶鈣比分析。結果發現不論是飼養在 20℃或 30℃，飼養於鹽度 0‰水體中的柳葉魚耳石鍶鈣比會從海洋柳葉魚階段的都 8‰降至 4‰以下，飼養於鹽度 10‰及 35‰的柳葉魚耳石鍶鈣比都則維持在 6-8‰之間。飼養於鹽度 0‰的耳石鍶鈣比明顯低於鹽度 10‰及 35‰的柳葉魚耳石鍶鈣比 ($p<0.005$), 飼養於鹽度 10‰及 35‰的柳葉魚耳石鍶鈣比間則無差異。飼養在 20℃或 30℃的耳石鍶鈣比間也無明顯差異 (Fig. 2)。顯示耳石鍶鈣比會受到環境水體中鹽度的影響 (Secor and Piccoli, 1996)。由鍶鈣比可以區別停留在淡水或海水之中，但卻無法區分低鹽度的河口域或高鹽度的海洋環境。

根據此實驗數據進行野生大眼海鰱洄游行為時發現大眼海鰱在柳葉魚階段生活於海洋，耳石鍶鈣比介於 8-11‰之間 (Fig. 3)。到了幼魚階段，洄游行為變的較為複雜，大致可分為三種 type。Type I：個體傾向於在海水或河口中成長 (耳石鍶鈣比大於 4‰) (Fig. 4a-b)；Type II：個體傾向於在淡水溪流中成長 (耳石鍶鈣比小於 4‰) (Fig. 4c-d)。Type III：個體在變態後會先進入淡水溪流中，之後會在淡水溪流和河口、海水間移動 (Fig. 4e)。在

大肚溪下游的採集站 (CT) 三種 type 都能發現到(Fig. 4)，但在中游的採集站只有 Type II (Fig. 5a-b)和 Type III (Fig. 5c-d)，顯示有些個體可能順著漲潮進入溪流下游攝食，但卻不會上溯至中游溪段。在海水中所捕獲的成魚及亞成魚的耳石鍶鈣比基本上屬於 Type III，因為最終都會回到海水中生殖。但還可再分為三種 sub type。Type IIIA：個體在變態後會先進入淡水溪流中，之後會在不同時期回到海水中(Fig. 6a-d)。Type IIIB：個體在變態後在海水中成長但偶爾會入侵溪流 (Fig. 6e)。Type IIIC：個體在變態後會在淡水及海水間移動 (Fig. 6f)。此實驗結果顯示：(1).大眼海鰱耳石鍶鈣比會受到環境中鹽度的影響。因此可由耳石鍶鈣比回推大眼海鰱洄游環境史。(2)、大眼海鰱在幼魚階段的洄游行為是隨機性的，因其為廣鹽性魚類且可直接呼吸空氣 (Wells et al., 2003)，使其能進入不同鹽度環境中攝食獵物。

六、計畫成果自評

本研究透過耳石之鍶鈣比 (Sr: Ca ratios) 技術，不但可重建大眼海鰱洄游環境史，並可由洄游環境史推測大眼海鰱的洄游行為及其對棲地的選擇性。對大眼海鰱基礎生物學的研究提供了更多的訊息。計畫進度已超越預期目標。此學術論文已完成，將發表於國際期刊。

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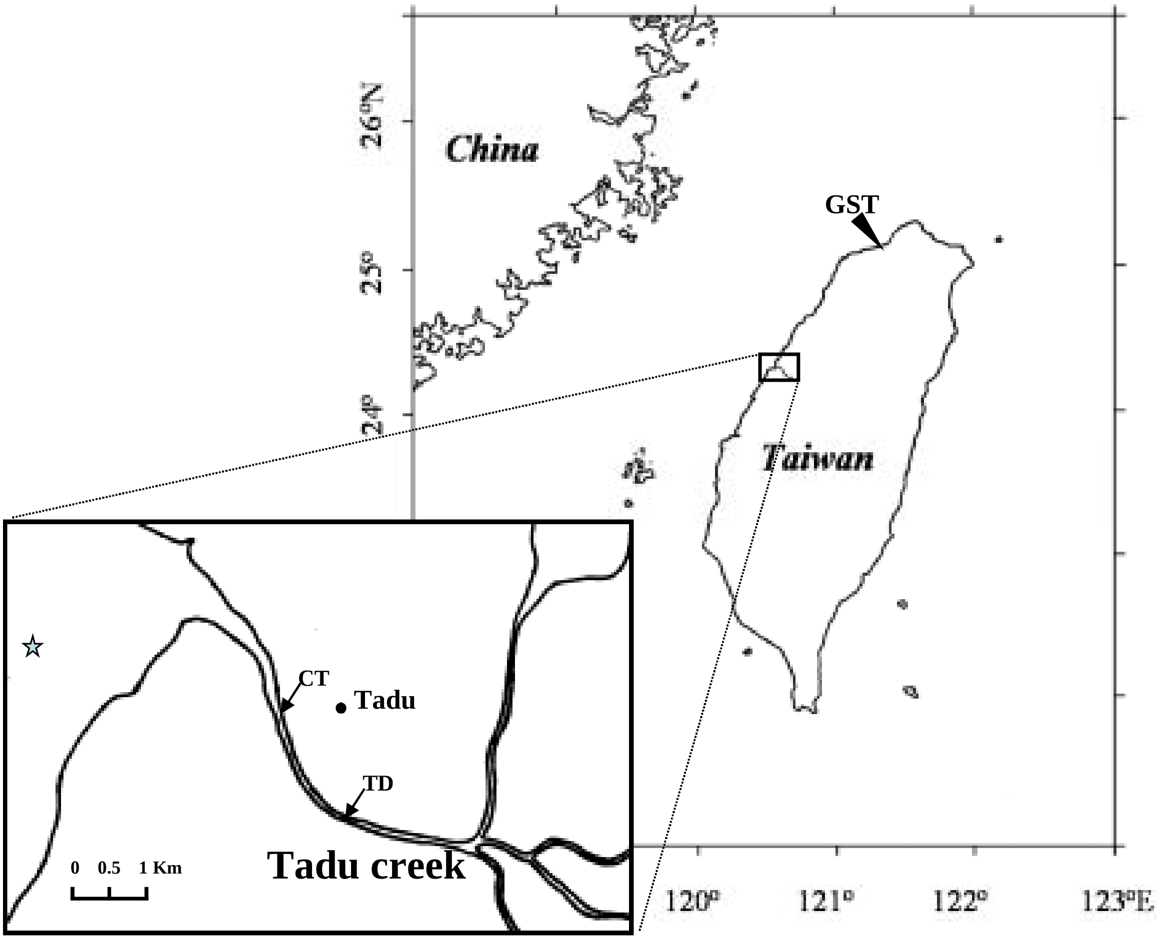

Fig. 1 The sampling locations of *M. cyprinoides* in the Gongshytyan Creek estuary (GST) of northern Taiwan, Tadu Creek (TD and CT) of central Taiwan and the coastal waters off Tadu Creek (★)

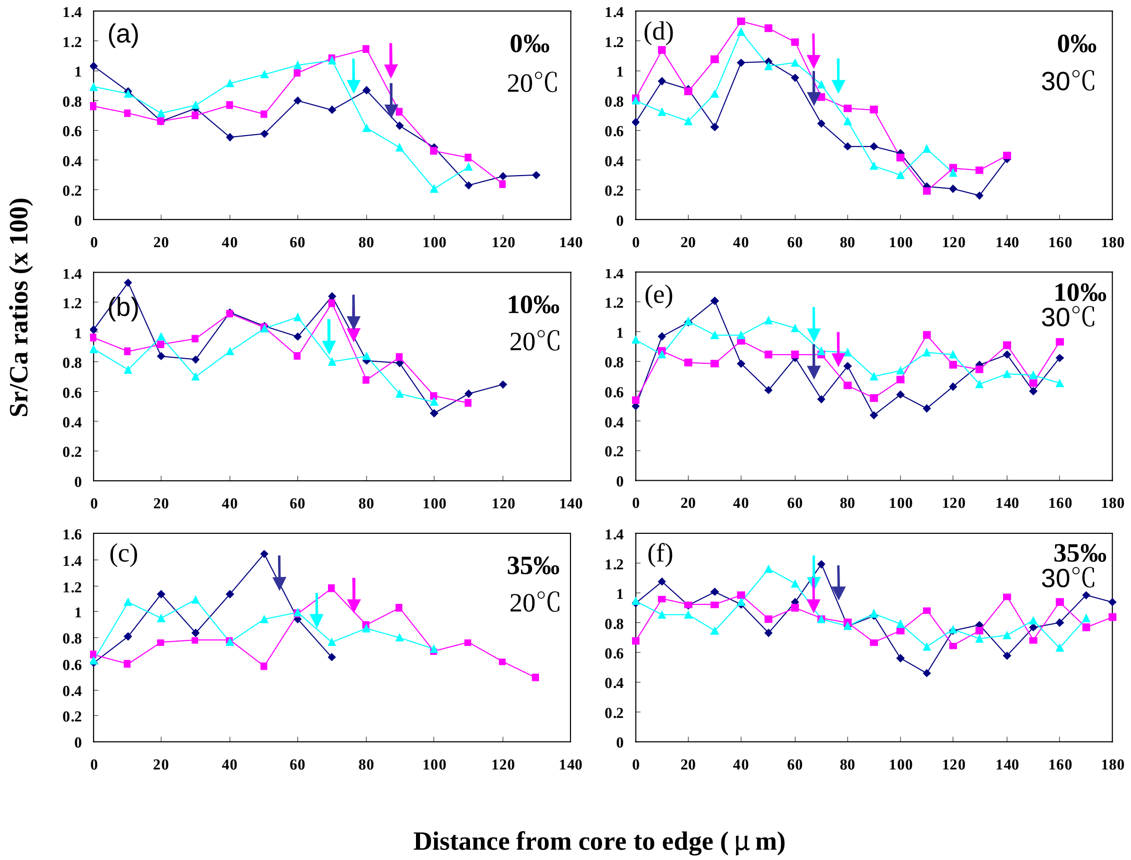

Fig.2 Changes in Sr/Ca ratios in otoliths of *M. cyprinoides* at the stage of metamorphosis from leptocephalus to juvenile which was cultivated at 2 different temperatures (20 and 30℃) and 3 different salinity 0‰ (a, d); 10‰ (b, e) and 35‰ (c, f). Arrow indicated the OTC mark.

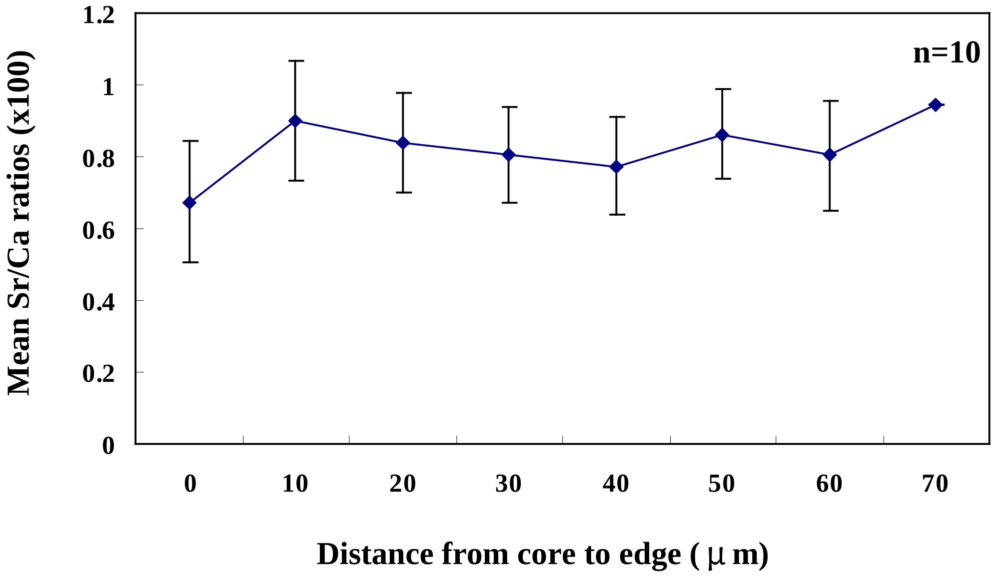

Fig. 3 Mean (±sd) Sr/Ca ratios of 10 newly recruited leptocephalus of *M. cyprinoides* collected from GST estuary.

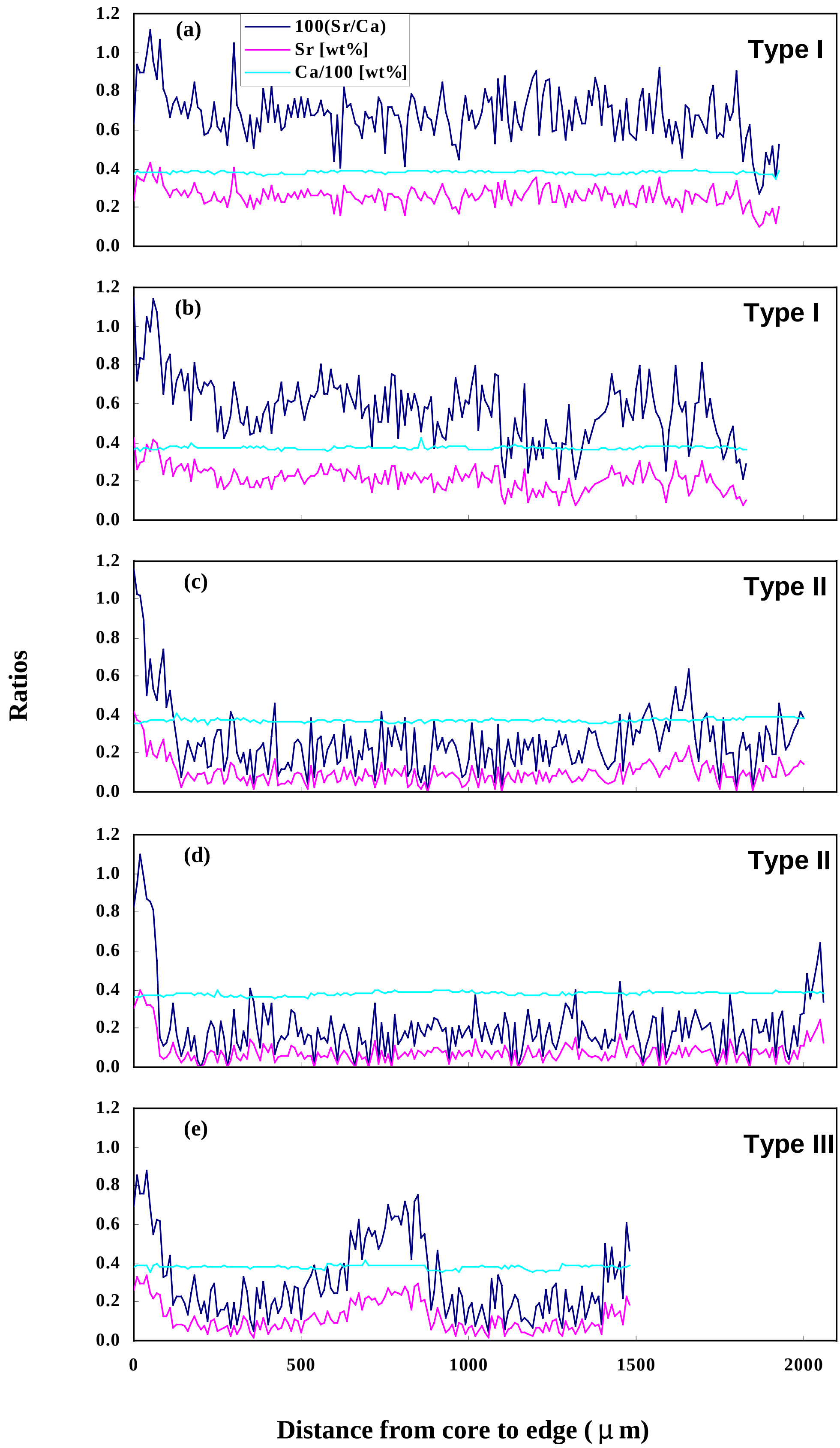

Fig.4 Sr/Ca ratios in otoliths of young *M. cyprinoides* collected in the lower reach (CT) of Tadu Creek. (a) 208.3mmFL, (b) 190mmFL, (c) 225.5mmFL, (d) 287.9mmFL, (e) 174.9mmFL.

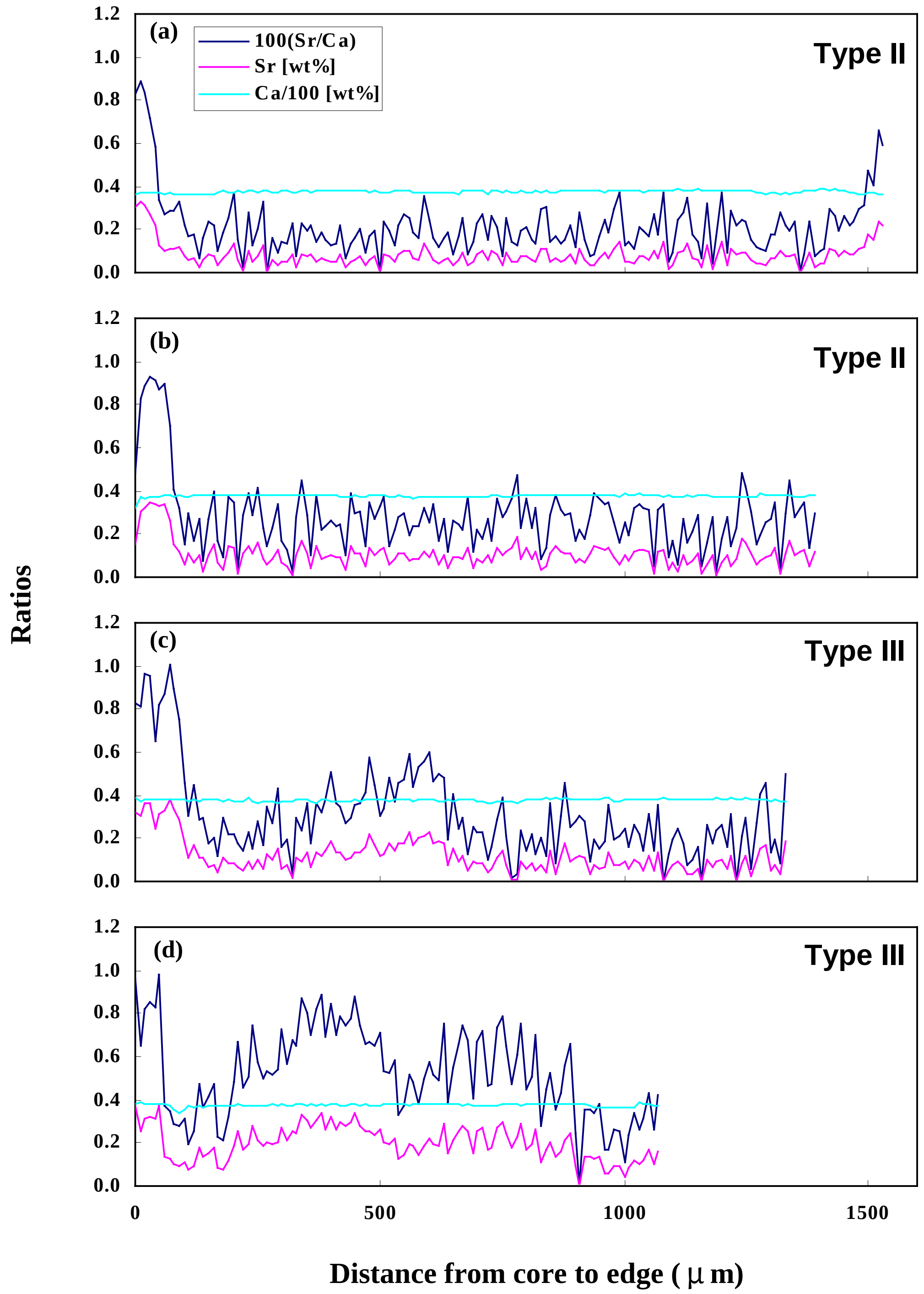

Fig.5 Sr/Ca ratios in otoliths of young *M. cyprinoides* collected in the low reach (TD) of Tadu Creek. (a) 264.1mmFL, (b) 252.9mmFL, (c) 247.1mmFL, (d) 226.3mmFL.

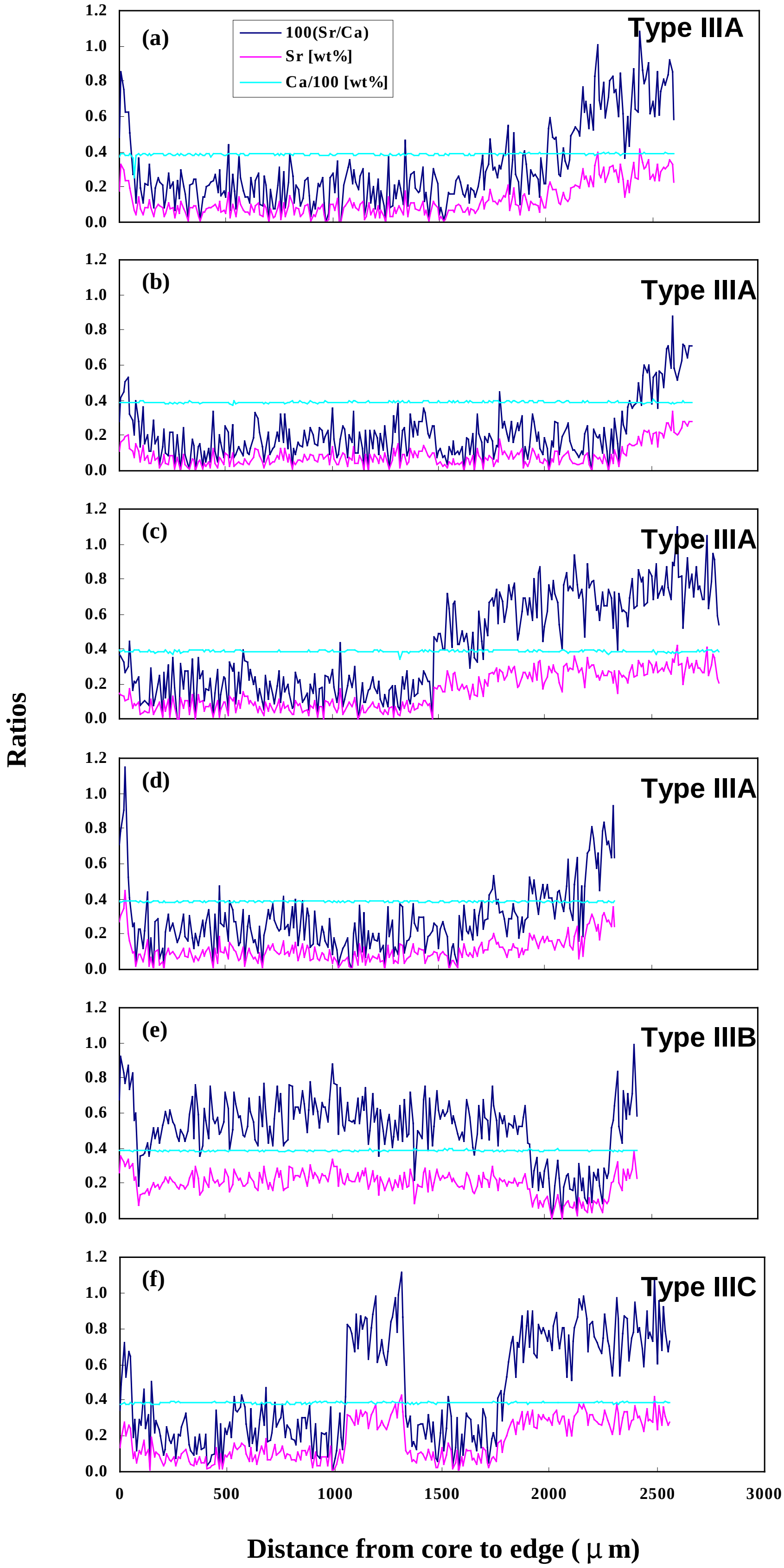

Fig.6 Sr/Ca ratios in otoliths of adult *M. cyprinoides* collected in the offshore of Tadu creek. (a) 391.2mmFL, (b) 276.1mmFL, (c) 349.5mmFL, (d) 300.2mmFL, (e) 391.9mmFL, (f) 384.3mmFL.