



HAL
open science

Discrimination of *Solea solea* nurseries along the French Atlantic coast using otolith elemental signatures

Eric D H Durieux, Maylis Labonne, Marie-Laure Bégout, Claire Bassoulet,
Hélène de Pontual

► **To cite this version:**

Eric D H Durieux, Maylis Labonne, Marie-Laure Bégout, Claire Bassoulet, Hélène de Pontual. Discrimination of *Solea solea* nurseries along the French Atlantic coast using otolith elemental signatures. 7th International Flatfish Symposium, Nov 2008, Sesimbra, Portugal. hal-00803364

HAL Id: hal-00803364

<https://hal.science/hal-00803364>

Submitted on 21 Mar 2013

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Discrimination of *Solea solea* nurseries along the French Atlantic coast using otolith elemental signatures

Eric D.H. Durieux¹, Maylis Labonne², Marie-Laure Bégout³, Claire Bassoulet⁴ & Hélène de Pontual²

¹ University of California Davis, One Shields Avenue, Davis, CA 95616, USA; ² Laboratoire de Sclérochronologie des Animaux Aquatiques, IFREMER - IRD, BP 70, 29280 Plouzané, France; ³ IFREMER, Place du Séminaire, BP 5 - 17137 L'Houmeau, France; ⁴ Institut Universitaire Européen de la Mer, Place Nicolas Copernic, 29280 Plouzané, France

Introduction

The common sole *Solea solea* (L.) is a commercially important and widely distributed flatfish of the North-East Atlantic. Like most demersal marine fishes around the world, sole stocks suffer from overexploitation. For the Bay of Biscay stock, sole nurseries display differences in terms of quantity (Le Pape et al. 2003) and quality (Gilliers et al. 2003). *In fine* the measure of the quality of a habitat for juveniles of a particular species is expressed by the contribution to the recruitment into the adult population (Beck et al. 2001). Understanding this connectivity between juvenile and adult habitats, i.e. evaluating the contribution of each nursery to a single adult stock appears essential in terms of stock management. However, this critical link is still missing for the Bay of Biscay stock.

Otoliths are calcium carbonate structures located in the inner ear of fish. Throughout the life of fish, otoliths grow continuously through accretion forming easily identifiable daily, seasonal and annual marks. During this process, they incorporate chemical elements that indirectly reflect the ambient conditions (e.g. temperature, chemical composition of the water) experienced by the fish. Due to these unique properties, otolith elemental composition analysis has become a powerful tool to determine the nursery origin in adult fish, to discriminate between stocks and sub-populations, and to reconstruct lifetime migration patterns (Campana & Thorrold 2001).

The aim of the present study was to determine if the main sole nurseries along the French Atlantic coast could be discriminated using otolith elemental composition analysis of age 0-group juveniles. This study constitutes the first step in evaluating the relative contribution of the different nurseries into the adult stock of the Bay of Biscay.

Material and methods

Fish collection and otolith preparation

0-group sole juveniles were sampled in 6 nurseries (embayed and estuarine) as part of the IFREMER sole nursery survey in the Bay of Biscay (Fig. 1) during September/October 2003 using a beam trawl (2.9 m wide and 0.5 m high, mounted with a 20 mm stretched mesh net at the codend) at 5-20 m depths. Fish were immediately frozen and stored individually at -20°C. Subsequently fish were measured (nearest mm), weighed (nearest 0.01 g) (Table 1) after which the sagittal otoliths were extracted, thoroughly cleaned of adhering tissue and then individually stored in plastic tubes. Only left otoliths were selected for multi-elemental analysis. Otoliths (n=119) were cleaned and decontaminated under a laminar flow positive pressure fume hood by: (1) immersion in ultraclean water, (2) immersion in 0.1% HNO₃ for 1 min (induced less than 2% loss in otolith weight), (3) double immersion in ultrapure water, (4) air dried for 24 hours and (5) stored in decontaminated polypropylene tubes.

Sample analysis

Multi-elemental composition was determined in whole otoliths using solution-based inductively coupled plasma mass spectrometry (ICP-MS, Thermo Element 2). The preparation for analysis was performed in a class 100 (ISO class 5) clean room.

Decontaminated otoliths were weighed on a precision scale to the nearest 0.1 µg (Table 1). Otoliths were dissolved in 15N HNO₃ and diluted proportionally to otolith mass (x1500) in ultrapure water overnight. The following elements were quantified: ⁷Li, ²³Na, ²⁴Mg, ⁴⁰Ca, ⁵⁵Mn, ⁸⁷Rb, ⁸⁹Sr, ⁹⁰Sr, ⁹¹Zr, ⁹²Zr, ⁹³Zr, ⁹⁴Zr, ⁹⁵Zr, ⁹⁶Zr, ⁹⁷Zr, ⁹⁸Zr, ⁹⁹Zr, ¹⁰⁰Zr, ¹⁰¹Zr, ¹⁰²Zr, ¹⁰³Zr, ¹⁰⁴Zr, ¹⁰⁵Zr, ¹⁰⁶Zr, ¹⁰⁷Zr, ¹⁰⁸Zr, ¹⁰⁹Zr, ¹¹⁰Zr, ¹¹¹Zr, ¹¹²Zr, ¹¹³Zr, ¹¹⁴Zr, ¹¹⁵Zr, ¹¹⁶Zr, ¹¹⁷Zr, ¹¹⁸Zr, ¹¹⁹Zr, ¹²⁰Zr, ¹²¹Zr, ¹²²Zr, ¹²³Zr, ¹²⁴Zr, ¹²⁵Zr, ¹²⁶Zr, ¹²⁷Zr, ¹²⁸Zr, ¹²⁹Zr, ¹³⁰Zr, ¹³¹Zr, ¹³²Zr, ¹³³Zr, ¹³⁴Zr, ¹³⁵Zr, ¹³⁶Zr, ¹³⁷Zr, ¹³⁸Zr, ¹³⁹Zr, ¹⁴⁰Zr, ¹⁴¹Zr, ¹⁴²Zr, ¹⁴³Zr, ¹⁴⁴Zr, ¹⁴⁵Zr, ¹⁴⁶Zr, ¹⁴⁷Zr, ¹⁴⁸Zr, ¹⁴⁹Zr, ¹⁵⁰Zr, ¹⁵¹Zr, ¹⁵²Zr, ¹⁵³Zr, ¹⁵⁴Zr, ¹⁵⁵Zr, ¹⁵⁶Zr, ¹⁵⁷Zr, ¹⁵⁸Zr, ¹⁵⁹Zr, ¹⁶⁰Zr, ¹⁶¹Zr, ¹⁶²Zr, ¹⁶³Zr, ¹⁶⁴Zr, ¹⁶⁵Zr, ¹⁶⁶Zr, ¹⁶⁷Zr, ¹⁶⁸Zr, ¹⁶⁹Zr, ¹⁷⁰Zr, ¹⁷¹Zr, ¹⁷²Zr, ¹⁷³Zr, ¹⁷⁴Zr, ¹⁷⁵Zr, ¹⁷⁶Zr, ¹⁷⁷Zr, ¹⁷⁸Zr, ¹⁷⁹Zr, ¹⁸⁰Zr, ¹⁸¹Zr, ¹⁸²Zr, ¹⁸³Zr, ¹⁸⁴Zr, ¹⁸⁵Zr, ¹⁸⁶Zr, ¹⁸⁷Zr, ¹⁸⁸Zr, ¹⁸⁹Zr, ¹⁹⁰Zr, ¹⁹¹Zr, ¹⁹²Zr, ¹⁹³Zr, ¹⁹⁴Zr, ¹⁹⁵Zr, ¹⁹⁶Zr, ¹⁹⁷Zr, ¹⁹⁸Zr, ¹⁹⁹Zr, ²⁰⁰Zr, ²⁰¹Zr, ²⁰²Zr, ²⁰³Zr, ²⁰⁴Zr, ²⁰⁵Zr, ²⁰⁶Zr, ²⁰⁷Zr, ²⁰⁸Zr, ²⁰⁹Zr, ²¹⁰Zr, ²¹¹Zr, ²¹²Zr, ²¹³Zr, ²¹⁴Zr, ²¹⁵Zr, ²¹⁶Zr, ²¹⁷Zr, ²¹⁸Zr, ²¹⁹Zr, ²²⁰Zr, ²²¹Zr, ²²²Zr, ²²³Zr, ²²⁴Zr, ²²⁵Zr, ²²⁶Zr, ²²⁷Zr, ²²⁸Zr, ²²⁹Zr, ²³⁰Zr, ²³¹Zr, ²³²Zr, ²³³Zr, ²³⁴Zr, ²³⁵Zr, ²³⁶Zr, ²³⁷Zr, ²³⁸Zr, ²³⁹Zr, ²⁴⁰Zr, ²⁴¹Zr, ²⁴²Zr, ²⁴³Zr, ²⁴⁴Zr, ²⁴⁵Zr, ²⁴⁶Zr, ²⁴⁷Zr, ²⁴⁸Zr, ²⁴⁹Zr, ²⁵⁰Zr, ²⁵¹Zr, ²⁵²Zr, ²⁵³Zr, ²⁵⁴Zr, ²⁵⁵Zr, ²⁵⁶Zr, ²⁵⁷Zr, ²⁵⁸Zr, ²⁵⁹Zr, ²⁶⁰Zr, ²⁶¹Zr, ²⁶²Zr, ²⁶³Zr, ²⁶⁴Zr, ²⁶⁵Zr, ²⁶⁶Zr, ²⁶⁷Zr, ²⁶⁸Zr, ²⁶⁹Zr, ²⁷⁰Zr, ²⁷¹Zr, ²⁷²Zr, ²⁷³Zr, ²⁷⁴Zr, ²⁷⁵Zr, ²⁷⁶Zr, ²⁷⁷Zr, ²⁷⁸Zr, ²⁷⁹Zr, ²⁸⁰Zr, ²⁸¹Zr, ²⁸²Zr, ²⁸³Zr, ²⁸⁴Zr, ²⁸⁵Zr, ²⁸⁶Zr, ²⁸⁷Zr, ²⁸⁸Zr, ²⁸⁹Zr, ²⁹⁰Zr, ²⁹¹Zr, ²⁹²Zr, ²⁹³Zr, ²⁹⁴Zr, ²⁹⁵Zr, ²⁹⁶Zr, ²⁹⁷Zr, ²⁹⁸Zr, ²⁹⁹Zr, ³⁰⁰Zr, ³⁰¹Zr, ³⁰²Zr, ³⁰³Zr, ³⁰⁴Zr, ³⁰⁵Zr, ³⁰⁶Zr, ³⁰⁷Zr, ³⁰⁸Zr, ³⁰⁹Zr, ³¹⁰Zr, ³¹¹Zr, ³¹²Zr, ³¹³Zr, ³¹⁴Zr, ³¹⁵Zr, ³¹⁶Zr, ³¹⁷Zr, ³¹⁸Zr, ³¹⁹Zr, ³²⁰Zr, ³²¹Zr, ³²²Zr, ³²³Zr, ³²⁴Zr, ³²⁵Zr, ³²⁶Zr, ³²⁷Zr, ³²⁸Zr, ³²⁹Zr, ³³⁰Zr, ³³¹Zr, ³³²Zr, ³³³Zr, ³³⁴Zr, ³³⁵Zr, ³³⁶Zr, ³³⁷Zr, ³³⁸Zr, ³³⁹Zr, ³⁴⁰Zr, ³⁴¹Zr, ³⁴²Zr, ³⁴³Zr, ³⁴⁴Zr, ³⁴⁵Zr, ³⁴⁶Zr, ³⁴⁷Zr, ³⁴⁸Zr, ³⁴⁹Zr, ³⁵⁰Zr, ³⁵¹Zr, ³⁵²Zr, ³⁵³Zr, ³⁵⁴Zr, ³⁵⁵Zr, ³⁵⁶Zr, ³⁵⁷Zr, ³⁵⁸Zr, ³⁵⁹Zr, ³⁶⁰Zr, ³⁶¹Zr, ³⁶²Zr, ³⁶³Zr, ³⁶⁴Zr, ³⁶⁵Zr, ³⁶⁶Zr, ³⁶⁷Zr, ³⁶⁸Zr, ³⁶⁹Zr, ³⁷⁰Zr, ³⁷¹Zr, ³⁷²Zr, ³⁷³Zr, ³⁷⁴Zr, ³⁷⁵Zr, ³⁷⁶Zr, ³⁷⁷Zr, ³⁷⁸Zr, ³⁷⁹Zr, ³⁸⁰Zr, ³⁸¹Zr, ³⁸²Zr, ³⁸³Zr, ³⁸⁴Zr, ³⁸⁵Zr, ³⁸⁶Zr, ³⁸⁷Zr, ³⁸⁸Zr, ³⁸⁹Zr, ³⁹⁰Zr, ³⁹¹Zr, ³⁹²Zr, ³⁹³Zr, ³⁹⁴Zr, ³⁹⁵Zr, ³⁹⁶Zr, ³⁹⁷Zr, ³⁹⁸Zr, ³⁹⁹Zr, ⁴⁰⁰Zr, ⁴⁰¹Zr, ⁴⁰²Zr, ⁴⁰³Zr, ⁴⁰⁴Zr, ⁴⁰⁵Zr, ⁴⁰⁶Zr, ⁴⁰⁷Zr, ⁴⁰⁸Zr, ⁴⁰⁹Zr, ⁴¹⁰Zr, ⁴¹¹Zr, ⁴¹²Zr, ⁴¹³Zr, ⁴¹⁴Zr, ⁴¹⁵Zr, ⁴¹⁶Zr, ⁴¹⁷Zr, ⁴¹⁸Zr, ⁴¹⁹Zr, ⁴²⁰Zr, ⁴²¹Zr, ⁴²²Zr, ⁴²³Zr, ⁴²⁴Zr, ⁴²⁵Zr, ⁴²⁶Zr, ⁴²⁷Zr, ⁴²⁸Zr, ⁴²⁹Zr, ⁴³⁰Zr, ⁴³¹Zr, ⁴³²Zr, ⁴³³Zr, ⁴³⁴Zr, ⁴³⁵Zr, ⁴³⁶Zr, ⁴³⁷Zr, ⁴³⁸Zr, ⁴³⁹Zr, ⁴⁴⁰Zr, ⁴⁴¹Zr, ⁴⁴²Zr, ⁴⁴³Zr, ⁴⁴⁴Zr, ⁴⁴⁵Zr, ⁴⁴⁶Zr, ⁴⁴⁷Zr, ⁴⁴⁸Zr, ⁴⁴⁹Zr, ⁴⁵⁰Zr, ⁴⁵¹Zr, ⁴⁵²Zr, ⁴⁵³Zr, ⁴⁵⁴Zr, ⁴⁵⁵Zr, ⁴⁵⁶Zr, ⁴⁵⁷Zr, ⁴⁵⁸Zr, ⁴⁵⁹Zr, ⁴⁶⁰Zr, ⁴⁶¹Zr, ⁴⁶²Zr, ⁴⁶³Zr, ⁴⁶⁴Zr, ⁴⁶⁵Zr, ⁴⁶⁶Zr, ⁴⁶⁷Zr, ⁴⁶⁸Zr, ⁴⁶⁹Zr, ⁴⁷⁰Zr, ⁴⁷¹Zr, ⁴⁷²Zr, ⁴⁷³Zr, ⁴⁷⁴Zr, ⁴⁷⁵Zr, ⁴⁷⁶Zr, ⁴⁷⁷Zr, ⁴⁷⁸Zr, ⁴⁷⁹Zr, ⁴⁸⁰Zr, ⁴⁸¹Zr, ⁴⁸²Zr, ⁴⁸³Zr, ⁴⁸⁴Zr, ⁴⁸⁵Zr, ⁴⁸⁶Zr, ⁴⁸⁷Zr, ⁴⁸⁸Zr, ⁴⁸⁹Zr, ⁴⁹⁰Zr, ⁴⁹¹Zr, ⁴⁹²Zr, ⁴⁹³Zr, ⁴⁹⁴Zr, ⁴⁹⁵Zr, ⁴⁹⁶Zr, ⁴⁹⁷Zr, ⁴⁹⁸Zr, ⁴⁹⁹Zr, ⁵⁰⁰Zr, ⁵⁰¹Zr, ⁵⁰²Zr, ⁵⁰³Zr, ⁵⁰⁴Zr, ⁵⁰⁵Zr, ⁵⁰⁶Zr, ⁵⁰⁷Zr, ⁵⁰⁸Zr, ⁵⁰⁹Zr, ⁵¹⁰Zr, ⁵¹¹Zr, ⁵¹²Zr, ⁵¹³Zr, ⁵¹⁴Zr, ⁵¹⁵Zr, ⁵¹⁶Zr, ⁵¹⁷Zr, ⁵¹⁸Zr, ⁵¹⁹Zr, ⁵²⁰Zr, ⁵²¹Zr, ⁵²²Zr, ⁵²³Zr, ⁵²⁴Zr, ⁵²⁵Zr, ⁵²⁶Zr, ⁵²⁷Zr, ⁵²⁸Zr, ⁵²⁹Zr, ⁵³⁰Zr, ⁵³¹Zr, ⁵³²Zr, ⁵³³Zr, ⁵³⁴Zr, ⁵³⁵Zr, ⁵³⁶Zr, ⁵³⁷Zr, ⁵³⁸Zr, ⁵³⁹Zr, ⁵⁴⁰Zr, ⁵⁴¹Zr, ⁵⁴²Zr, ⁵⁴³Zr, ⁵⁴⁴Zr, ⁵⁴⁵Zr, ⁵⁴⁶Zr, ⁵⁴⁷Zr, ⁵⁴⁸Zr, ⁵⁴⁹Zr, ⁵⁵⁰Zr, ⁵⁵¹Zr, ⁵⁵²Zr, ⁵⁵³Zr, ⁵⁵⁴Zr, ⁵⁵⁵Zr, ⁵⁵⁶Zr, ⁵⁵⁷Zr, ⁵⁵⁸Zr, ⁵⁵⁹Zr, ⁵⁶⁰Zr, ⁵⁶¹Zr, ⁵⁶²Zr, ⁵⁶³Zr, ⁵⁶⁴Zr, ⁵⁶⁵Zr, ⁵⁶⁶Zr, ⁵⁶⁷Zr, ⁵⁶⁸Zr, ⁵⁶⁹Zr, ⁵⁷⁰Zr, ⁵⁷¹Zr, ⁵⁷²Zr, ⁵⁷³Zr, ⁵⁷⁴Zr, ⁵⁷⁵Zr, ⁵⁷⁶Zr, ⁵⁷⁷Zr, ⁵⁷⁸Zr, ⁵⁷⁹Zr, ⁵⁸⁰Zr, ⁵⁸¹Zr, ⁵⁸²Zr, ⁵⁸³Zr, ⁵⁸⁴Zr, ⁵⁸⁵Zr, ⁵⁸⁶Zr, ⁵⁸⁷Zr, ⁵⁸⁸Zr, ⁵⁸⁹Zr, ⁵⁹⁰Zr, ⁵⁹¹Zr, ⁵⁹²Zr, ⁵⁹³Zr, ⁵⁹⁴Zr, ⁵⁹⁵Zr, ⁵⁹⁶Zr, ⁵⁹⁷Zr, ⁵⁹⁸Zr, ⁵⁹⁹Zr, ⁶⁰⁰Zr, ⁶⁰¹Zr, ⁶⁰²Zr, ⁶⁰³Zr, ⁶⁰⁴Zr, ⁶⁰⁵Zr, ⁶⁰⁶Zr, ⁶⁰⁷Zr, ⁶⁰⁸Zr, ⁶⁰⁹Zr, ⁶¹⁰Zr, ⁶¹¹Zr, ⁶¹²Zr, ⁶¹³Zr, ⁶¹⁴Zr, ⁶¹⁵Zr, ⁶¹⁶Zr, ⁶¹⁷Zr, ⁶¹⁸Zr, ⁶¹⁹Zr, ⁶²⁰Zr, ⁶²¹Zr, ⁶²²Zr, ⁶²³Zr, ⁶²⁴Zr, ⁶²⁵Zr, ⁶²⁶Zr, ⁶²⁷Zr, ⁶²⁸Zr, ⁶²⁹Zr, ⁶³⁰Zr, ⁶³¹Zr, ⁶³²Zr, ⁶³³Zr, ⁶³⁴Zr, ⁶³⁵Zr, ⁶³⁶Zr, ⁶³⁷Zr, ⁶³⁸Zr, ⁶³⁹Zr, ⁶⁴⁰Zr, ⁶⁴¹Zr, ⁶⁴²Zr, ⁶⁴³Zr, ⁶⁴⁴Zr, ⁶⁴⁵Zr, ⁶⁴⁶Zr, ⁶⁴⁷Zr, ⁶⁴⁸Zr, ⁶⁴⁹Zr, ⁶⁵⁰Zr, ⁶⁵¹Zr, ⁶⁵²Zr, ⁶⁵³Zr, ⁶⁵⁴Zr, ⁶⁵⁵Zr, ⁶⁵⁶Zr, ⁶⁵⁷Zr, ⁶⁵⁸Zr, ⁶⁵⁹Zr, ⁶⁶⁰Zr, ⁶⁶¹Zr, ⁶⁶²Zr, ⁶⁶³Zr, ⁶⁶⁴Zr, ⁶⁶⁵Zr, ⁶⁶⁶Zr, ⁶⁶⁷Zr, ⁶⁶⁸Zr, ⁶⁶⁹Zr, ⁶⁷⁰Zr, ⁶⁷¹Zr, ⁶⁷²Zr, ⁶⁷³Zr, ⁶⁷⁴Zr, ⁶⁷⁵Zr, ⁶⁷⁶Zr, ⁶⁷⁷Zr, ⁶⁷⁸Zr, ⁶⁷⁹Zr, ⁶⁸⁰Zr, ⁶⁸¹Zr, ⁶⁸²Zr, ⁶⁸³Zr, ⁶⁸⁴Zr, ⁶⁸⁵Zr, ⁶⁸⁶Zr, ⁶⁸⁷Zr, ⁶⁸⁸Zr, ⁶⁸⁹Zr, ⁶⁹⁰Zr, ⁶⁹¹Zr, ⁶⁹²Zr, ⁶⁹³Zr, ⁶⁹⁴Zr, ⁶⁹⁵Zr, ⁶⁹⁶Zr, ⁶⁹⁷Zr, ⁶⁹⁸Zr, ⁶⁹⁹Zr, ⁷⁰⁰Zr, ⁷⁰¹Zr, ⁷⁰²Zr, ⁷⁰³Zr, ⁷⁰⁴Zr, ⁷⁰⁵Zr, ⁷⁰⁶Zr, ⁷⁰⁷Zr, ⁷⁰⁸Zr, ⁷⁰⁹Zr, ⁷¹⁰Zr, ⁷¹¹Zr, ⁷¹²Zr, ⁷¹³Zr, ⁷¹⁴Zr, ⁷¹⁵Zr, ⁷¹⁶Zr, ⁷¹⁷Zr, ⁷¹⁸Zr, ⁷¹⁹Zr, ⁷²⁰Zr, ⁷²¹Zr, ⁷²²Zr, ⁷²³Zr, ⁷²⁴Zr, ⁷²⁵Zr, ⁷²⁶Zr, ⁷²⁷Zr, ⁷²⁸Zr, ⁷²⁹Zr, ⁷³⁰Zr, ⁷³¹Zr, ⁷³²Zr, ⁷³³Zr, ⁷³⁴Zr, ⁷³⁵Zr, ⁷³⁶Zr, ⁷³⁷Zr, ⁷³⁸Zr, ⁷³⁹Zr, ⁷⁴⁰Zr, ⁷⁴¹Zr, ⁷⁴²Zr, ⁷⁴³Zr, ⁷⁴⁴Zr, ⁷⁴⁵Zr, ⁷⁴⁶Zr, ⁷⁴⁷Zr, ⁷⁴⁸Zr, ⁷⁴⁹Zr, ⁷⁵⁰Zr, ⁷⁵¹Zr, ⁷⁵²Zr, ⁷⁵³Zr, ⁷⁵⁴Zr, ⁷⁵⁵Zr, ⁷⁵⁶Zr, ⁷⁵⁷Zr, ⁷⁵⁸Zr, ⁷⁵⁹Zr, ⁷⁶⁰Zr, ⁷⁶¹Zr, ⁷⁶²Zr, ⁷⁶³Zr, ⁷⁶⁴Zr, ⁷⁶⁵Zr, ⁷⁶⁶Zr, ⁷⁶⁷Zr, ⁷⁶⁸Zr, ⁷⁶⁹Zr, ⁷⁷⁰Zr, ⁷⁷¹Zr, ⁷⁷²Zr, ⁷⁷³Zr, ⁷⁷⁴Zr, ⁷⁷⁵Zr, ⁷⁷⁶Zr, ⁷⁷⁷Zr, ⁷⁷⁸Zr, ⁷⁷⁹Zr, ⁷⁸⁰Zr, ⁷⁸¹Zr, ⁷⁸²Zr, ⁷⁸³Zr, ⁷⁸⁴Zr, ⁷⁸⁵Zr, ⁷⁸⁶Zr, ⁷⁸⁷Zr, ⁷⁸⁸Zr, ⁷⁸⁹Zr, ⁷⁹⁰Zr, ⁷⁹¹Zr, ⁷⁹²Zr, ⁷⁹³Zr, ⁷⁹⁴Zr, ⁷⁹⁵Zr, ⁷⁹⁶Zr, ⁷⁹⁷Zr, ⁷⁹⁸Zr, ⁷⁹⁹Zr, ⁸⁰⁰Zr, ⁸⁰¹Zr, ⁸⁰²Zr, ⁸⁰³Zr, ⁸⁰⁴Zr, ⁸⁰⁵Zr, ⁸⁰⁶Zr, ⁸⁰⁷Zr, ⁸⁰⁸Zr, ⁸⁰⁹Zr, ⁸¹⁰Zr, ⁸¹¹Zr, ⁸¹²Zr, ⁸¹³Zr, ⁸¹⁴Zr, ⁸¹⁵Zr, ⁸¹⁶Zr, ⁸¹⁷Zr, ⁸¹⁸Zr, ⁸¹⁹Zr, ⁸²⁰Zr, ⁸²¹Zr, ⁸²²Zr, ⁸²³Zr, ⁸²⁴Zr, ⁸²⁵Zr, ⁸²⁶Zr, ⁸²⁷Zr, ⁸²⁸Zr, ⁸²⁹Zr, ⁸³⁰Zr, ⁸³¹Zr, ⁸³²Zr, ⁸³³Zr, ⁸³⁴Zr, ⁸³⁵Zr, ⁸³⁶Zr, ⁸³⁷Zr, ⁸³⁸Zr, ⁸³⁹Zr, ⁸⁴⁰Zr, ⁸⁴¹Zr, ⁸⁴²Zr, ⁸⁴³Zr, ⁸⁴⁴Zr, ⁸⁴⁵Zr, ⁸⁴⁶Zr, ⁸⁴⁷Zr, ⁸⁴⁸Zr, ⁸⁴⁹Zr, ⁸⁵⁰Zr, ⁸⁵¹Zr, ⁸⁵²Zr, ⁸⁵³Zr, ⁸⁵⁴Zr, ⁸⁵⁵Zr, ⁸⁵⁶Zr, ⁸⁵⁷Zr, ⁸⁵⁸Zr, ⁸⁵⁹Zr, ⁸⁶⁰Zr, ⁸⁶¹Zr, ⁸⁶²Zr, ⁸⁶³Zr, ⁸⁶⁴Zr, ⁸⁶⁵Zr, ⁸⁶⁶Zr, ⁸⁶⁷Zr, ⁸⁶⁸Zr, ⁸⁶⁹Zr, ⁸⁷⁰Zr, ⁸⁷¹Zr, ⁸⁷²Zr, ⁸⁷³Zr, ⁸⁷⁴Zr, ⁸⁷⁵Zr, ⁸⁷⁶Zr, ⁸⁷⁷Zr, ⁸⁷⁸Zr, ⁸⁷⁹Zr, ⁸⁸⁰Zr, ⁸⁸¹Zr, ⁸⁸²Zr, ⁸⁸³Zr, ⁸⁸⁴Zr, ⁸⁸⁵Zr, ⁸⁸⁶Zr, ⁸⁸⁷Zr, ⁸⁸⁸Zr, ⁸⁸⁹Zr, ⁸⁹⁰Zr, ⁸⁹¹Zr, ⁸⁹²Zr, ⁸⁹³Zr, ⁸⁹⁴Zr, ⁸⁹⁵Zr, ⁸⁹⁶Zr, ⁸⁹⁷Zr, ⁸⁹⁸Zr, ⁸⁹⁹Zr, ⁹⁰⁰Zr, ⁹⁰¹Zr, ⁹⁰²Zr, ⁹⁰³Zr, ⁹⁰⁴Zr, ⁹⁰⁵Zr, ⁹⁰⁶Zr, ⁹⁰⁷Zr, ⁹⁰⁸Zr, ⁹⁰⁹Zr, ⁹¹⁰Zr, ⁹¹¹Zr, ⁹¹²Zr, ⁹¹³Zr, ⁹¹⁴Zr, ⁹¹⁵Zr, ⁹¹⁶Zr, ⁹¹⁷Zr, ⁹¹⁸Zr, ⁹¹⁹Zr, ⁹²⁰Zr, ⁹²¹Zr, ⁹²²Zr, ⁹²³Zr, ⁹²⁴Zr, ⁹²⁵Zr, ⁹²⁶Zr, ⁹²⁷Zr, ⁹²⁸Zr, ⁹²⁹Zr, ⁹³⁰Zr, ⁹³¹Zr, ⁹³²Zr, ⁹³³Zr, ⁹³⁴Zr, ⁹³⁵Zr, ⁹³⁶Zr, ⁹³⁷Zr, ⁹³⁸Zr, ⁹³⁹Zr, ⁹⁴⁰Zr, ⁹⁴¹Zr, ⁹⁴²Zr, ⁹⁴³Zr, ⁹⁴⁴Zr, ⁹⁴⁵Zr, ⁹⁴⁶Zr, ⁹⁴⁷Zr, ⁹⁴⁸Zr, ⁹⁴⁹Zr, ⁹⁵⁰Zr, ⁹⁵¹Zr, ⁹⁵²Zr, ⁹⁵³Zr, ⁹⁵⁴Zr, ⁹⁵⁵Zr, ⁹⁵⁶Zr, ⁹⁵⁷Zr, ⁹⁵⁸Zr, ⁹⁵⁹Zr, ⁹⁶⁰Zr, ⁹⁶¹Zr, ⁹⁶²Zr, ⁹⁶³Zr, ⁹⁶⁴Zr, ⁹⁶⁵Zr, ⁹⁶⁶Zr, ⁹⁶⁷Zr, ⁹⁶⁸Zr, ⁹⁶⁹Zr, ⁹⁷⁰Zr, ⁹⁷¹Zr, ⁹⁷²Zr, ⁹⁷³Zr, ⁹⁷⁴Zr, ⁹⁷⁵Zr, ⁹⁷⁶Zr, ⁹⁷⁷Zr, ⁹⁷⁸Zr, ⁹⁷⁹Zr, ⁹⁸⁰Zr, ⁹⁸¹Zr, ⁹⁸²Zr, ⁹⁸³Zr, ⁹⁸⁴Zr, ⁹⁸⁵Zr, ⁹⁸⁶Zr, ⁹⁸⁷Zr, ⁹⁸⁸Zr, ⁹⁸⁹Zr, ⁹⁹⁰Zr, ⁹⁹¹Zr, ⁹⁹²Zr, ⁹⁹³Zr, ⁹⁹⁴Zr, ⁹⁹⁵Zr, ⁹⁹⁶Zr, ⁹⁹⁷Zr, ⁹⁹⁸Zr, ⁹⁹⁹Zr, ¹⁰⁰⁰Zr, ¹⁰⁰¹Zr, ¹⁰⁰²Zr, ¹⁰⁰³Zr, ¹⁰⁰⁴Zr, ¹⁰⁰⁵Zr, ¹⁰⁰⁶Zr, ¹⁰⁰⁷Zr, ¹⁰⁰⁸Zr, ¹⁰⁰⁹Zr, ¹⁰¹⁰Zr, ¹⁰¹¹Zr, ¹⁰¹²Zr, ¹⁰¹³Zr, ¹⁰¹⁴Zr, ¹⁰¹⁵Zr, ¹⁰¹⁶Zr, ¹⁰¹⁷Zr, ¹⁰¹⁸Zr, ¹⁰¹⁹Zr, ¹⁰²⁰Zr, ¹⁰²¹Zr, ¹⁰²²Zr, ¹⁰²³Zr, ¹⁰²⁴Zr, ¹⁰²⁵Zr, ¹⁰²⁶Zr, ¹⁰²⁷Zr, ¹⁰²⁸Zr, ¹⁰²⁹Zr, ¹⁰³⁰Zr, ¹⁰³¹Zr, ¹⁰³²Zr, ¹⁰³³Zr, ¹⁰³⁴Zr, ¹⁰³⁵Zr, ¹⁰³⁶Zr, ¹⁰³⁷Zr, ¹⁰³⁸Zr, ¹⁰³⁹Zr, ¹⁰⁴⁰Zr, ¹⁰⁴¹Zr, ¹⁰⁴²Zr, ¹⁰⁴³Zr, ¹⁰⁴⁴Zr, ¹⁰⁴⁵Zr, ¹⁰⁴⁶Zr, ¹⁰⁴⁷Zr, ¹⁰⁴⁸Zr, ¹⁰⁴⁹Zr, ¹⁰⁵⁰Zr, ¹⁰⁵¹Zr, ¹⁰⁵²Zr, ¹⁰⁵³Zr, ¹⁰⁵⁴Zr, ¹⁰⁵⁵Zr, ¹⁰⁵⁶Zr, ¹⁰⁵⁷Zr, ¹⁰⁵⁸Zr, ¹⁰⁵⁹Zr, ¹⁰⁶⁰Zr, ¹⁰⁶¹Zr, ¹⁰⁶²Zr, ¹⁰⁶³Zr, ¹⁰⁶⁴Zr, ¹⁰⁶⁵Zr, ¹⁰⁶⁶Zr, <