Geophysical Research Abstracts
Vol. 16, EGU2014-2764, 2014
EGU General Assembly 2014

The $^{87}Sr/^{86}Sr$ aquatic isoscape of the Danube catchment from the source to the mouth as tool for studying fish migrations

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Isoscapes - spatially distributed isotope patterns across landscapes - are increasingly used as important basis for ecological studies. The natural variation of the isotopic abundances in a studied area bears the potential to be used as natural tracer for studying e.g. migrations of animals or prey-predator relations. The $^{87}Sr/^{86}Sr$ ratio is one important tracer, since it is known to provide a direct relation of biological samples to geologically distinct regions, as Sr isotopes are incorporated into living tissues as a proxy for calcium and taken up from the environment without any significant fractionation.

Although until now the focus has been mainly set on terrestrial systems, maps for aquatic systems are increasingly being established. Here we present the first $^{87}Sr/^{86}Sr$ aquatic isoscape of the Danube catchment, the second largest river catchment in Europe, from near its source starting at river km 2581 in Germany down to its mouth to river km 107 in Romania. The total length of the river Danube is 2780 km draining a catchment area 801 463 km^2 (10 % of the European continent). The major purpose of this study was to assess the potential of the $^{87}Sr/^{86}Sr$ isotope ratio to be used as tool for studying fish migrations at different scales in the entire Danube catchment. Within the Joint Danube Research 3 (JDS 3), the biggest scientific multi-disciplinary river expedition of the World in 2013 aiming at the assessment of the ecological status and degree of human alterations along the river Danube, water samples were taken at 68 pre-defined sites along the course of the river Danube including the major tributaries as a basis to create the so called 'Isoscape of the Danube catchment'.

The determination of $^{87}Sr/^{86}Sr$ isotope ratio in river water was performed by multicollector-sector field-inductively coupled plasma-mass spectrometry (MC-SF-ICP-MS). The JDS 3 data were combined with existing data from prior studies conducted within the Austrian part of the Danube catchment. Finally, the dominating geological formations in the catchment upstream of the sampling site were determined using ArcGIS.

Analyses of water samples yielded several 'Isozones' along the course of the Danube, indicating diverse geological conditions. Studying migration phenomena of fish using natural isotopic marks in hard parts is especially possible between these 'Isozones'. In geologically similar regions with little differences in the $^{87}Sr/^{86}Sr$ isotope ratio, element distributions or artificial marking methods (tagging, spiking) can be used complementarily. A significant positive relationship between the $^{87}Sr/^{86}Sr$ ratio in river water and the proportion of siliceous geological formations in the catchment was found. Moreover, the $^{87}Sr/^{86}Sr$ isotope ratio along the Austrian part of the Danube and its tributaries proved to be stable between seasons. The strong relation of the geology of a catchment to the $^{87}Sr/^{86}Sr$ isotope ratios in river water provides the possibility to predict the $^{87}Sr/^{86}Sr$ ratios in river water by the dominating geology in river catchments, for an estimation of the general applicability of the $^{87}Sr/^{86}Sr$ ratio in European rivers to fish ecological questions.