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Erratum: Lead–radium dating of orange roughy (*Hoplostethus atlanticus*): validation of a centenarian life span

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Ref.: Can. J. Fish. Aquat. Sci. **66**: 1130–1140, 2009.

An error occurred during typesetting of the article that mistakenly reported radon-222 (^{222}Rn) as radium-222 (^{222}Ra). All instances of ^{222}Ra in four paragraphs on pp. 1136–1137 of the Discussion should be ^{222}Rn. These paragraphs have been corrected and reprinted below.

The seminal radiometric study on orange roughy by Fenton et al. (1991) used pooled whole otolith samples and an approach that made it necessary to make some educated assumptions. The study did not perform any growth zone derived age estimations, but instead sought to independently determine age for groups of fish with similar length and otolith weight. For the method to work, there needed to be little or no (*i*) between-individual variability in otolith mass growth rate and (*ii*) variability in ^{226}Ra uptake throughout the growth of the otolith. In addition to these factors, there were important assumptions about the very nature of the lead–radium dating technique; the otolith needed to be a closed system to (*i*) the ingrowth of ^{210}Pb from ^{226}Ra with no loss of ^{226}Ra daughter products and (*ii*) the incorporation of exogenous sources of the decay series radionuclides (not from the decay of incorporated ^{226}Ra). Within these assumptions, the most conceivable problems were (*i*) the potential loss of ^{222}Rn (daughter product of ^{226}Ra and a noble gas) and (*ii*) the incorporation of exogenous ^{210}Pb or polonium-210 (used as a proxy for ^{210}Pb in alpha-spectrometry). These concerns could not be thoroughly addressed when Fenton et al. (1991) performed the analyses on orange roughy otoliths, but subsequent studies have provided support for the assumptions that were necessary (Francis 1995; Smith et al. 1995). In some cases, the assumptions have been tested directly.

The veracity of the lead–radium technique was questioned by a number of papers addressing the assumptions. In a perspective paper, West and Gauldie (1994) argued that there were uncontrollable errors that invalidated the technique for fish age estimation but provided a series of observations and conclusions that failed to consider equally viable explanations that do not discredit the radiometric technique. In an attempt to measure loss of ^{222}Rn from orange roughy otoliths, Gauldie and Cremer (1998) openly recognized anomalous results, a faulted technique, and negative values that imply the contrary; nevertheless, they concluded from weak trends in rather dubious data that loss of ^{222}Rn was a problem and that this invalidated old ages. The inconclusive quality of those data was reiterated in a follow-up application that reported a loss of 26%–28% (Gauldie and Cremer 2000), but these findings are inconsistent with determinations made in this study because large losses as such would create an upper limit to the measured lead–radium ratios. Furthermore, evidence supporting the author's conclusions was cited (e.g., incomplete concepts from a report by Whitehead and Ditchburn (1996)), but a prior publication that (*i*) specifically addressed ^{222}Rn diffusion from orange roughy otoliths and (*ii*) provided evidence to support a long life span (Whitehead and Ditchburn 1995) was ignored (i.e., Gauldie and Cremer 1998, 2000; Gauldie and Romanek 1998).

Perhaps the most scientifically robust study to date on potential loss of ^{222}Rn from otoliths was performed on red snapper (*Lutjanus campechanus*) and red drum (*Sciaenops ocellatus*) from the Gulf of Mexico (Baker et al. 2001). In this study, two species with relatively large otoliths and some of the highest ^{226}Ra activities recorded from otolith material were analyzed; the study resulted in low ($\leq$4.1%) to no loss of ^{222}Rn. The measured loss was further considered more of a surface emanation because larger otoliths liberated relatively less ^{222}Rn. They concluded that such losses were probably insignificant relative to other sources of error associated with lead–radium dating. This would be

Received 30 July 2009. Accepted 30 July 2009. Published on the NRC Research Press Web site at cjfas.nrc.ca on 20 August 2009.
J21329

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especially true in the case of otolith cores because the loss would be temporary and much less significant with time. In another study, Pacific halibut (*Hippoglossus stenolepis*) otoliths revealed no evidence of ^{222}Rn loss, but experimental error from low lead–radium levels led to somewhat inconclusive results (Kastelle and Forsberg 2002).

Another scenario to consider with regard to loss of ^{222}Rn is the potential affect on the measured lead–radium ratio as age approaches 100 years. In a study performed on yelloweye rockfish (*Sebastes ruberrimus*), otolith cores provided measured lead–radium ratios that were very close to secular equilibrium (Andrews et al. 2002). If there was a consistent problem with the loss of ^{222}Rn throughout the period of otolith growth, then secular equilibrium would not and could not be attained. It was at approximately 99 years that secular equilibrium was approached to within 95% for the ingrowth model used in the present study (core age of 4 years). Provided that there was a ^{222}Rn loss on the order of 25% for the oldest orange roughy age group (90–108 years with an average age of 98 years), the measured ratio (1.007, 2 SE low of 0.9461) would have been far less, approximately 0.675 and a radiometric age of 30–40 years. In addition, none of the samples analyzed in this study, as well as other studies (e.g., Andrews et al. 2002), would have exceeded this ratio. The findings presented here for orange roughy support the hypothesis that loss of ^{222}Rn was not a significant factor in the determination of age from lead–radium dating.