



Otoliths as recorders of palaeoenvironments: comparison of radiocarbon age and isoleucine epimerization in Pleistocene golden perch *Macquaria ambigua* otoliths from Willandra Lakes.

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Fish otoliths, calcium carbonate gravity and auditory receptors in the membranous labyrinths of teleost fish, can provide environmental data that are valuable to a wide range of disciplines. Otoliths form by the accretion of layers of calcium carbonate and organic-rich material that often form distinctive layers over time scales ranging from days to years. These layers are not resorbed during the life of the fish and have potential to provide data relevant to both the biology of the fish and the environment to which the fish has been exposed. Environmental variability based on otoliths can be estimated through measures of stable oxygen isotopes, trace elements, and the widths of both daily and annual increments. Because many fish species can live for 50 years or more, it is feasible to recover, from otoliths, time series of proxy environmental data over several decades (Kalish 1994). Before otolith-derived data can be applied to studies of climate change, it is necessary to develop methods to date samples. Although otoliths can be dated based on measurement of radiocarbon by accelerator mass spectrometry this method is relatively expensive.

An alternative method for dating golden perch otoliths is based on measurements of isoleucine D/L ratios. Miller and Rosewater (1995) demonstrated that golden perch otoliths are near a perfect closed system for racemization and that otoliths have potential of dating surrounding sediments older than 100 ka. Despite the suitability of these structures for racemization measurements, many of collections of Pleistocene otoliths from Willandra Lakes are not appropriate for determination of sample age. Most otoliths sampled in the region have been derived from surface collections, while it is recommended that samples should have been buried at least 1 m during most of their history. Therefore, the majority of existing otolith collections are not appropriate for geochronology or palaeothermometry. Nevertheless, when used in conjunction with radiocarbon dates, racemization data may be of value in assessing the relationship among otoliths in an assemblage. Radiocarbon ages and isoleucine D/L ratios were determined for 30 otoliths collected from Willandra Lakes. The rostrum of each otolith was analysed for D/L ratios and a portion of the posterior of the same otolith was analysed for radiocarbon by accelerator mass spectrometry. Sample weights for both analyses ranged from 14.0 to 25.6 mg. The central portion of the otolith was sectioned serially in the transverse plane and these sections were prepared for trace element and stable isotope analyses.

Extensive erosion and surface runoff at Willandra Lakes, as exemplified by the Walls of China, suggests that otoliths obtained in surface collections may derive from localities a significant distance from the point of collection. Although radiocarbon dates can isolate samples within a temporal framework, further information would be required to define spatial relationships. For example, three otoliths collected at Mulurulu I had radiocarbon ages of 16250, 16350 and 16200. These same samples had D/L ratios of 0.101, 0.120, and 0.106 suggesting that they experienced similar thermal regimes and burial histories. This conclusion is further supported by similar chronologies of otolith ring (annual increment) widths and Sr/Ca ratios measured across transverse sections of these otoliths. Alternatively, 8 otolith samples from the Lake Garnpung lunette had radiocarbon dates and D/L ratios between 14,500-15,600 and 0.138-0.272, respectively. This suggests these otoliths experienced very different burial histories despite their similar ages and that they may have been transported some distance from their original site.

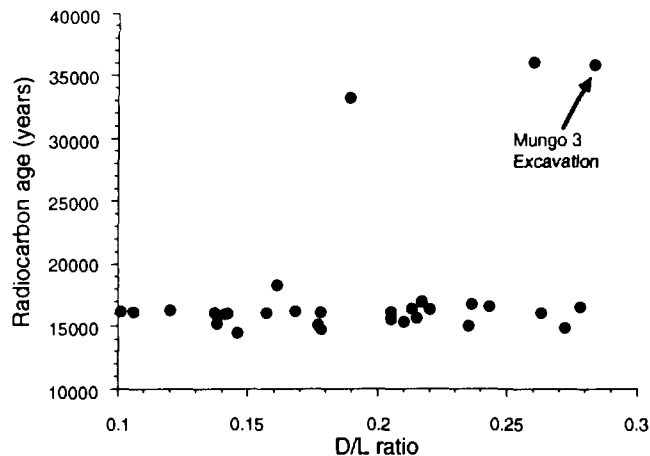


Figure 1. D/L ratios and radiocarbon ages determined from 30 golden perch (*Macquaria ambigua*) otoliths collected at Willandra Lakes. Most samples were from surface collections. One sample was excavated from a depth of over 1 m near the Mungo 3 site.

Temporal information from radiocarbon, combined with spatial inference from D/L ratios and site of collection can be used to ascertain the relatedness of otoliths associated with Pleistocene hearths on the Mungo Surface Collection area. For example, 2 otoliths collected at a hearth (B1 Mungo grid reference) had radiocarbon ages of $16,150 \pm 370$ and $16,550 \pm 440$ and D/L ratios of 0.263 and 0.278. These data suggest similar burial histories and increase the likelihood that these samples were directly associated with the hearth. Otolith chemical and increment width data support the conclusion that these samples are linked temporally and spatially. Otoliths from adjacent surface collection sites (C1 and D1 Mungo grid references) had similar radiocarbon ages 16,200-16,600, but a relatively wide range of D/L ratios from 0.168-0.243. Although, these samples were adjacent to the B1 locality at the time of collection and have similar radiocarbon ages, the D/L ratios suggest that some samples experienced different burial histories. It may be that some of these otoliths were not associated with hearths and were transported across the lunette to collection sites by wind and water.

The longevity of the Pleistocene golden perch indicates that annual and decadal records of climate change can be derived from their otoliths. Preliminary investigations on Willandra Lakes otoliths have found that Pleistocene golden perch from Lakes Garnpung, Mulurulu, and Mungo had mean ages of 22.2 ± 10 ($n=42$), 20.3 ± 5 ($n=36$), and 9.4 ± 3 ($n=20$) years, respectively. The maximum age was 53 years for a fish from Lake Garnpung.

The ability of golden perch otoliths to record environmental change has been confirmed from studies of both modern and ancient populations. Microprobe transects across golden perch otoliths record salinity increases associated with drought events. In some cases, drought events are recorded at the otolith edge; these were undoubtedly the cause of the fish's death. Other otoliths record single or multiple drought events that occurred many years before death. In these situations, the fish may have been consumed by aboriginals for food, particularly if the otolith was associated with a hearth, or it may have died from other causes.

Literature Cited

Kalish, J.M. 1994. Investigating global change and fish biology with fish otolith radiocarbon. *Nuclear Instruments and Methods B* 92:421-425.

Miller, G.H., and Rosewater, A. (1995) The potential of isoleucine epimerization in fish otoliths to date Pleistocene archaeological sites. *Annual Meeting Geol Soc Amer Abstracts*