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Radionuclides and metals in fish and freshwater mussels from Mudginberri and Sandy Billabongs, Alligator Rivers Region, 2000–2003

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Contents

Figures

Tables

Plain English summary

We have now finished measuring radium in mussels from collections taken in May 2000, October 2000, September 2001, October 2002, and October 2003 and fish in 2000 and 2002. All of the mussel results are summarised in Table 4–8, also included are results from 1983 and 1986 providing more historical data for comparison.

The mussel results from October 2000, September 2001, October 2002 and October 2003 are lower than for the previous collections (comparing the results for the same age group of mussels). We believe that the reason for this is that these later sets of mussels were taken from the upstream end of the billabong, whereas the earlier collections were either from the eastern side of the billabong about halfway down (1983, 1986), or at the outlet (May 2000). This explanation makes sense because the quartz sand in the creek bed upstream and at the inlet has naturally lower radium concentrations than the finer mud in the billabong itself. We dont think the apparent drop in concentrations is due to the different times of year the mussels were collected. This is because mussels have more tissue mass in May than in October, so if anything we would expect radium concentrations to increase seasonally from May to October (though we dont have the data to prove this).

Overall, on the evidence we have at present, there is no obvious trend for Ra-226 concentrations to be increasing with time (for the same mussel ages and sampling location). If there was an influence by Ranger Uranium Mine on radionuclide concentrations in mussels from Mudginberri this would be very small and we can not see it. This is also true for fish although our dataset is not as long.

In future monitoring, we intend to continue collecting mussels at or near the inlet, as this is where Aboriginal people collect them to eat. We will also continue to collect fish every second year. This is a good example of the importance of getting input into our sample collections from Aboriginal people. We value this input very much and hope that collaboration on this can continue. It appears that location in the billabong is important, and we need to keep an eye on this in our collections.

Radionuclides and metals in fish and freshwater mussels from Mudginberri and Sandy Billabongs, Alligator Rivers Region, 2000–2003

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Introduction

Over the past two decades the Supervising Scientist has developed radiological, chemical, ecotoxicological and biological techniques that are used to monitor and assess impacts upon ecosystems and humans that arise from mining activities. During the 2000/2001 Wet season a monitoring program was implemented to collect relevant environmental data for the monitoring of Ranger Uranium Mine in Kakadu National Park (Figure 1).

This report summarises data for radionuclide concentrations in aquatic animals that have been collected by the Environmental Research Institute of the Supervising Scientist (***eriss***) for Mudginberri Billabong (beginning in May 2000) and Sandy Billabong (commencing in October 2002). The report also presents some historical data for mussels and fish collected during the 1980s and 1990s, see Table 1 for details. The main purpose of this report is to act as a record and data summary to help with the full analysis of the data. Although some preliminary discussion of the results is presented here, significant analysis, including statistical and modelling analysis, remains to be carried out. The results of this analysis and modelling work will be presented in subsequent publications.

Sites

Mudginberri Billabong (WGS 84 53 L UTM 269350 8607010) is on the Magela Creek system, located approximately 11 kilometres downstream of the Ranger Uranium Mine (Figure 2). Sandy Billabong (WGS 84 53 L UTM 0259248 8572422) is on the Nourlangie Creek system (Figure 3) and is being sampled as a control site. Summary data indicating the sample locations and date of collection are summarised in Table 1.

Freshwater mussels (*Velesunio angasi*) were collected from the outlet of Mudginberri Billabong during May 2000 by ***eriss*** staff and Traditional Owners. In October 2000 and September 2001 mussels were collected from the inlet of Mudginberri Billabong at a large sandbar. The collection was carried out by ***eriss*** staff, Traditional Owners and Aboriginal people from the Mudginberri community. These locations are used by the local Aboriginal people to collect freshwater mussels as part of their normal consumption of bushfoods. In October 2002, mussels were collected by hand along the eastern bank of Mudginberri Billabong approximately 150 metres from the inlet end, by Traditional Owners and Aboriginal people from the Mudginberri community. In October 2003, mussels were collected from the same location as the previous year using a small dredge. The Mudginberri collection locations are illustrated in Figure 4. The 2002 and 2003 mussel collections from Sandy Billabong were collected from the same location each year, approximately 30 metres upstream of the boat ramp in the middle of the billabong on the western bank. The mussels were hand collected in 2002 and a dredge was used for collection in 2003.

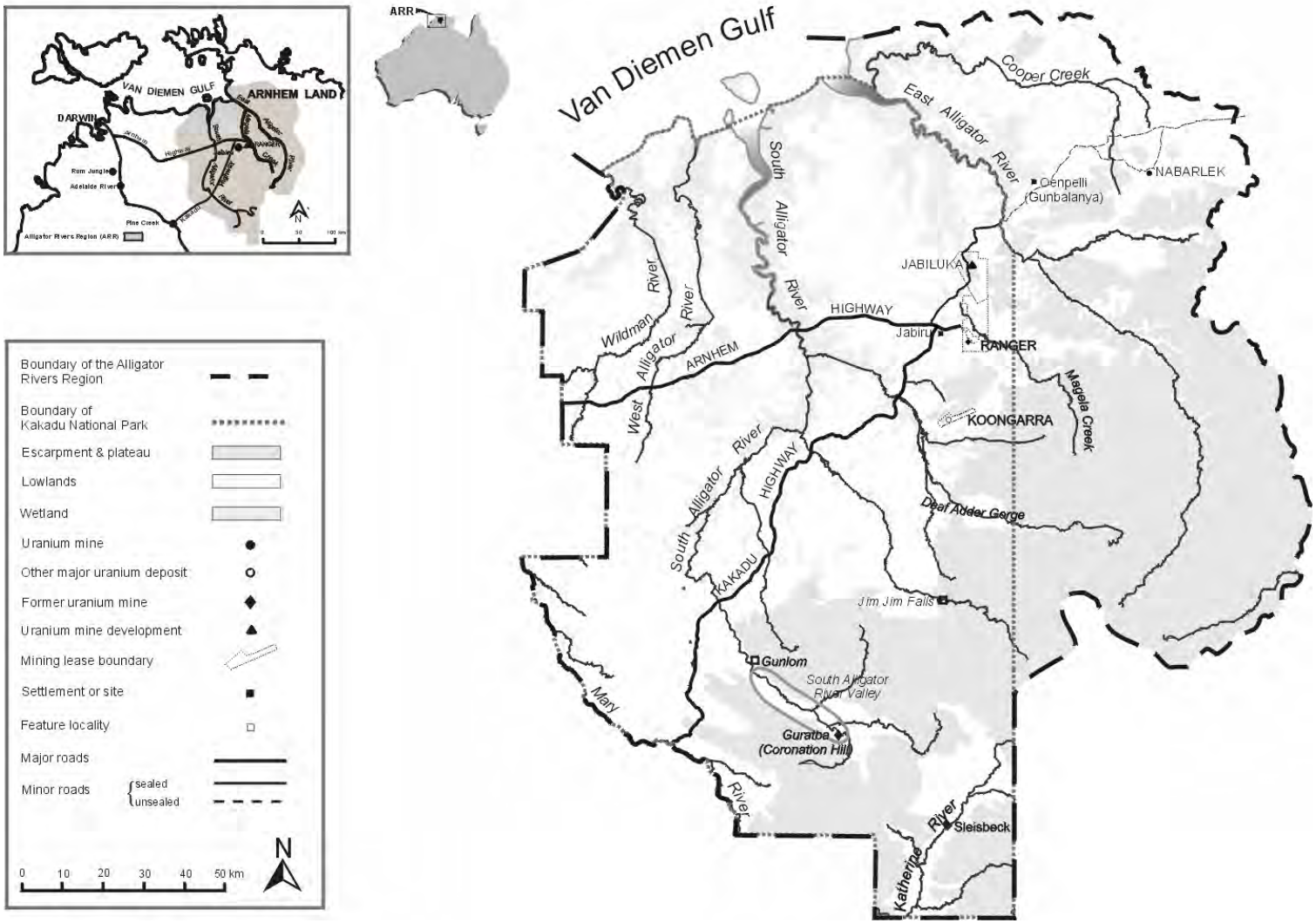

Figure 1 Map of the Alligator Rivers region, Northern Territory, Australia

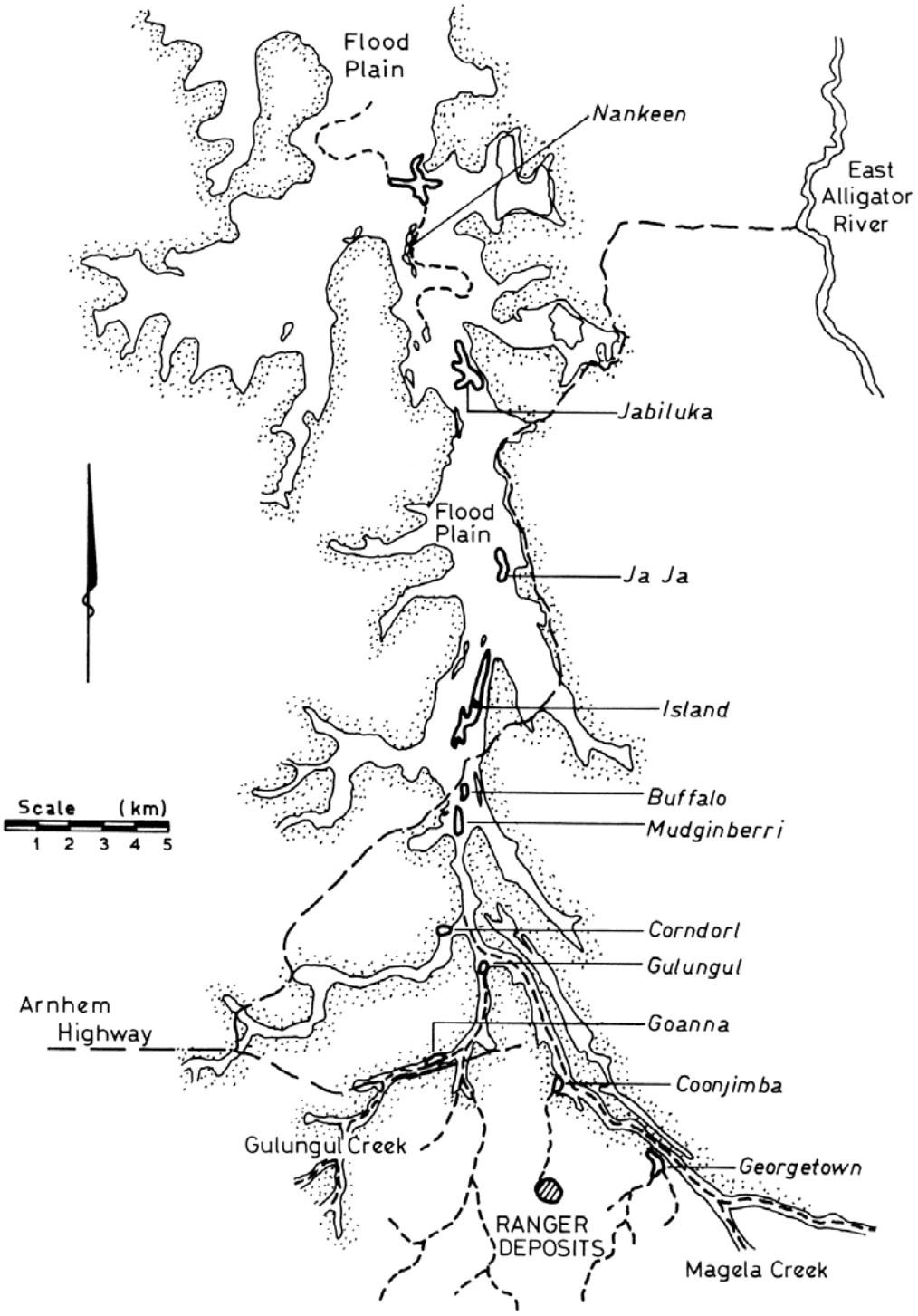

Figure 2 Magela Creek billabongs (Marchant 1982)

Table 1 Summary of collections and methods of analysis presented in this report

Collection date	Location	Sample	Gravimetric	ICPMS	Gamma Spectroscopy	Alpha Spectroscopy
			Physical	Chemical	Radionuclide	Radionuclide
February 1983	Mudginberri	Mussel			√	
February 1986	Mudginberri	Mussel			√	
August 1985	Mudginberri	Fish		√		√
December 1985	Mudginberri	Fish		√		
February 1988	Mudginberri	Fish		√		
March 1988	Mudginberri	Fish		√		
February 1995	Mudginberri	Fish		√		
May 2000	Mudginberri	Fish	√		√	√
October 2000	Mudginberri	Mussel	√	√	√	
September 2001	Mudginberri	Mussel	√	√	√	
October 2002	Mudginberri	Mussel	√	√	√	
October 2002	Sandy Billabong	Mussel	√	√	√	
October 2002	Mudginberri	Fish	√			√
October 2002	Sandy Billabong	Fish	√			√
October 2003	Mudginberri	Mussel	√	√	√	
October 2003	Sandy Billabong	Mussel	√	√	√	
September 2003	Mudginberri	Fish	√	√		
September 2003	Sandy Billabong	Fish	√	√		

The majority of fish analysed from Mudginberri and Sandy billabongs were catfish. Other species analysed included samples of bony bream, tarpon and saratoga. In 2000 and 2002 the fish were collected from various points in Mudginberri Billabong at approximately the same time as the mussel collections. The 2003 fish collections were collected in September 2003 and again from various points in the billabong.

For the first time, in October 2002, fish were collected from Sandy Billabong on the Nourlangie Creek system (Figure 3), tissues from these animals are being used as control samples. The fish were collected from various points in Sandy Billabong in 2002 and 2003.

Water samples were collected from most sites at the time of fish and mussel collection. Sediment samples were taken during mussel collections, a sediment sample was not collected for the May 2000 Mudginberri Billabong mussel collection.

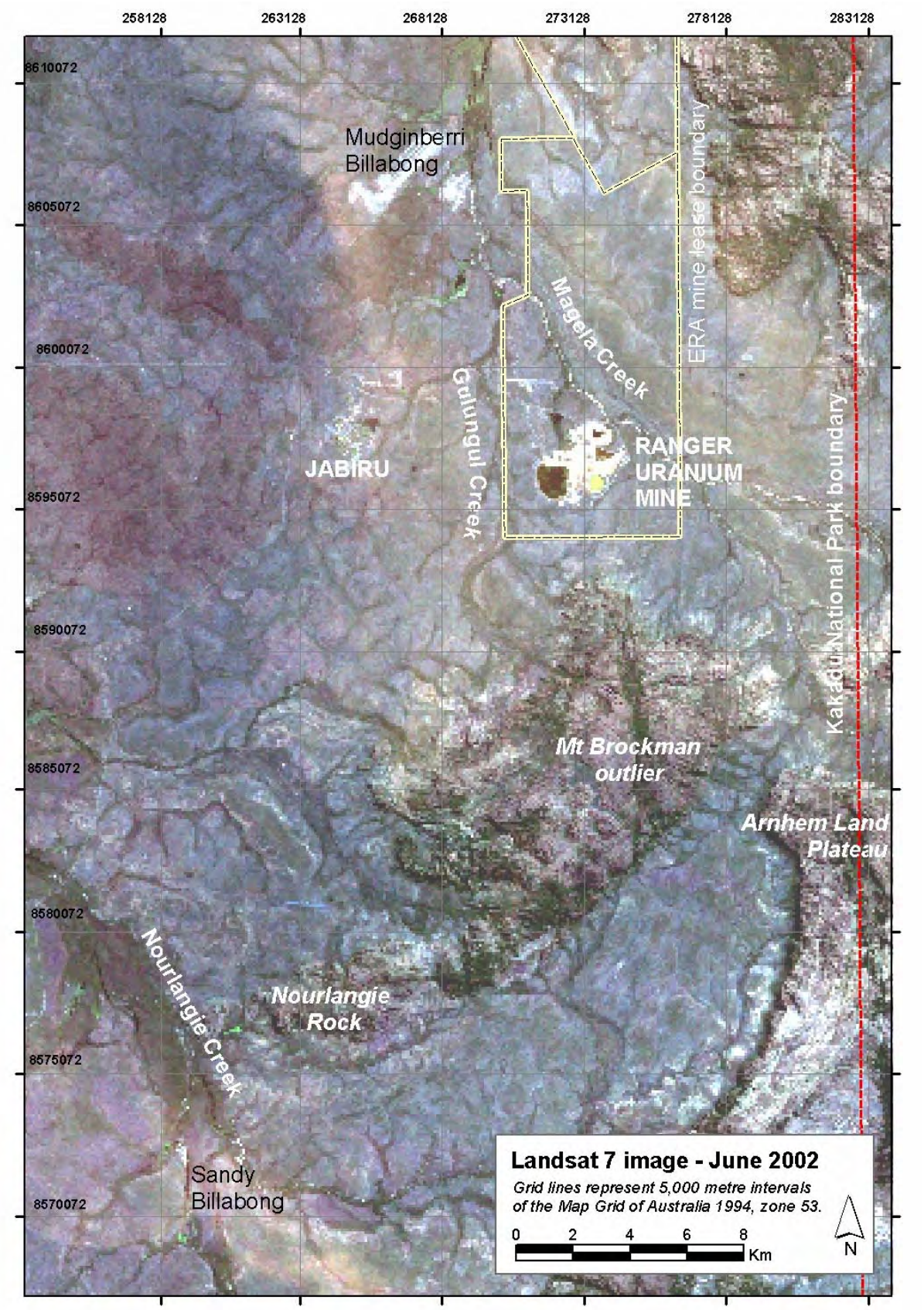

Figure 3 Landsat image showing Sandy Billabong on the Nourlangie Creek system and its relationship to the Ranger Uranium Mine project area

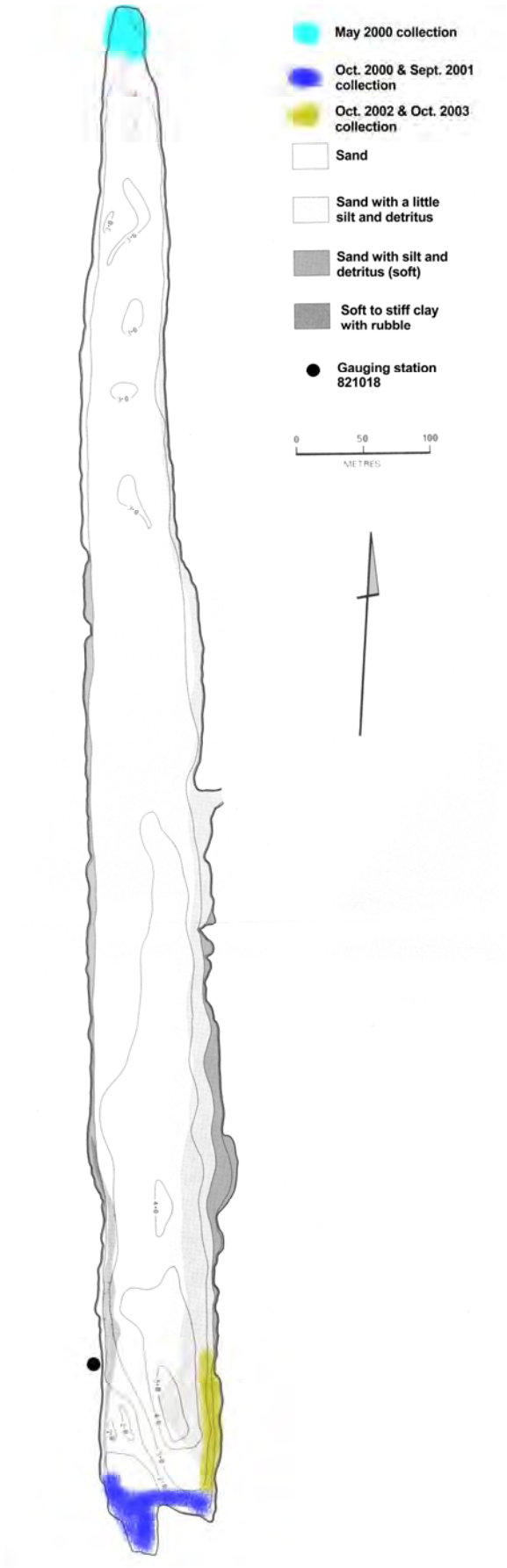

Figure 4 Bathymetric map of Mudginberri billabong showing mussel collection sites from 2000, 2001 and 2002 (modified from Humphrey 1984)

Analytical methods

For all sample types (water, sediment, mussels and fish) radionuclide activities and radioisotope ratios were determined by either alpha or gamma spectrometry, or in the case of ^{238}U, by calculation from the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) value using the conversion factor of 1 Bq ^{238}U = 80.962 μg of natural U. Details of the alpha spectrometry methods are described in Martin & Hancock (1992), Sill (1987) and the gamma spectrometry methods in Murray et al. (1987), Marten (1992) and Pfitzner (1994).

Concentrations of metals in waters, sediments and mussels were determined by ICP-MS at Charles Darwin University (CDU) and results are reported in Appendix B, D, F, I, K, M, P and T.

Errors provided in the radionuclide summary tables, figures and text are one estimated standard deviation based upon counting statistics only. Detection limits for each sample vary depending on sample size, detector efficiency and background, chemical recovery and background concentrations of the given nuclide. A value is deemed to be below detection limit if it is less than twice the standard deviation for that sample. In such cases a less than value is recorded being two times the standard deviation plus the calculated value (or zero if greater).

Water samples

Surface water samples were collected in acid-washed plastic 5 litre containers. The samples were filtered in the laboratory to < 0.45 μm within 24 hours of collection and the filtrate acidified to ~1% HNO_3 (AnalR). The residue was digested with concentrated HCl and then concentrated HNO_3.

Both the filtrate and digested residue were analysed for radioisotopes of polonium (^{210}Po), and radium (^{226}Ra) by alpha spectrometry (Appendix C). A sub sample of each filtrate (acidified with Aristar grade nitric acid) and digested residue solution was sent for ICP-MS analysis to determine the concentrations of barium (Ba), magnesium (Mg), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd) and uranium (U). Results for this analysis are in Appendix B and I.

Sediment samples

Between 300 and 400 grams of sediment were collected for each mussel collection. The sediment matter the mussels were living in was taken from the bottom of the billabong below the water line. The top 3–5 cm of the bottom of the billabong was scraped and put into zip lock plastic bags and taken to the ***eriss*** laboratory for processing.

Sediment samples were oven dried at 60° C for 3 days, ground with a ring mill and cast in resin for determination of radioisotopes of lead (^{210}Pb), thorium (^{228}Th) and radium (^{226}Ra and ^{228}Ra) by gamma spectrometry (Appendix E and L). Sub samples of the dried, ground sediments were analysed by ICP-MS, the analysis included, aluminium (Al), arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), rhenium (Re), rubidium (Rb), selenium (Se), sodium (Na), sulphur (S), uranium (U), zinc (Zn) (Appendix D and K).

Mussels

Mussels were collected from the billabong then placed immediately into an acid washed container holding host billabong water. After collection, mussels were transported to the ***eriss*** laboratory. The mussels were purged over 6-7 days at room temperature, in aerated filtered host billabong water. After purging, the mussels were measured for length and width (Appendix O and S), weighed and dissected to remove the visceral mass (flesh) using the methods of Allison and Simpson (1983) then placed onto trays for weighing and oven dried at 60^0C for 7 days. The trays used may have influenced the ICPMS Al results and the results should be interpreted accordingly. After drying, the mussels were reweighed to determine the dry weight and ground using a sample grinder and a mortar and pestle.

The age of each mussel was determined by placing the shell over an incandescent light source and counting the (annual) dark bands (annuli) (Humphrey & Simpson 1985). The ages of the mussels need to be adjusted by adding seven months to the number of annuli as most mussels are recruited during the wet season; hence in October they are N annuli and a half years of age. The dried and ground flesh of each mussel was combined according to age class and site, and a composite sample of each age class was cast in resin for determination of radioisotopes of lead (^{210}Pb), thorium (^{228}Th) and radium (^{226}Ra & ^{228}Ra) by gamma spectrometry (Appendix R & U). Mussels ≤ 1 year of age, or an age class with insufficient mass (< 2 g) for analysis by gamma spectrometry, were analysed by alpha spectrometry (Appendix Q).

Fish

All fish from May 2000, October 2002 and September 2003 were collected using gill nets. During each collection, several nets with different mesh sizes were set in positions around the billabong and the fish collected from the nets at regular intervals. The fish were narcotised by cooling in water on ice and then killed by freezing (recommended euthanasia method 8, CDU). The fish were then taken back to the ***eriss*** laboratory and dissected using stainless steal forceps and disposable sterilised scalpels, removing the liver and kidneys. The organ samples from 2000 were sent to NTEL for metal analysis (Appendix F) and the 2002 and 2003 samples were sent to CDU for metal analysis (Appendix F and M). Muscle tissue was also cut from the fish and the skin removed. The fish organs and muscle tissue were placed in trays and oven dried at 60° C for 7 days. The trays used may have influenced the ICPMS Al results and the results should be interpreted accordingly. After drying, the fish samples were reweighed to determine the dry weight and ground, using a sample grinder and a mortar and pestle, in preparation for analysis. ^{226}Ra and ^{210}Po were analysed by alpha spectrometry and the results are listed in Appendix G.

Results and discussion

Results are summarised and presented in tabular form in the attached Appendices. As the main purpose of this report is to provide a description of sample collection and sample analysis, and to summarise the results, only a brief analysis of the data is presented here.

Water samples

Table 2 provides a summary of radionuclide results for water collected from Mudginberri and Sandy billabongs. The results for particulate and filtrate analysis are presented in Appendices B, C, I and J.

Table 2 Radionuclide activity concentrations for water (filtrate) by site. ^{238}U results from U analysis by ICP-MS

Site	Collection date	^{238}U (µg/L)	^{238}U (mBq/L)	^{226}Ra (mBq/L)	^{210}Po (mBq/L)
Mudginberri B/B	May 2000	0.14	1.73	3.83	1.54
Mudginberri B/B	October 2000			1.17	
Mudginberri B/B	September 2001	0.02	0.25		0.36
Mudginberri B/B	October 2002	0.03	0.37	2.1	0.65
Sandy B/B	October 2002	0.02	0.25	< 1	

Sediment samples

A summary of analytical radionuclide results for sediments is given in Table 3 and Appendices D, E. K and L. ^{226}Ra activity concentrations for October 2000 and September 2001 are similar, as are the results for October 2002 and 2003. This is not unexpected as the 2000 and 2001 samples were collected from the same locations on the billabong as were the 2002 and 2003 sample collections (Figure 4). Measured ^{226}Ra activity concentrations in Mudginberri Billabong sediments are higher than in Sandy Billabong sediments and may be an artefact of the mineralised catchment area of the Magela Creek.

Table 3 Radionuclide activity concentrations and activity ratios for sediments by site and collection date

Site	Date	^{226}Ra (Bq/kg dry wt)	^{228}Ra (Bq/kg dry wt)	^{40}K (Bq/kg dry wt)	$^{228}Ra/^{226}Ra$
Mudginberri	Oct 2000	11.0 ± 1.0	6.6 ± 1.9	-	0.60 ± 0.35
Mudginberri	Sept 2001	11.7 ± 0.9	16.9 ± 1.7	-	1.44 ± 0.18
Mudginberri	Oct 2002	19.1 ± 1.4	9.3 ± 2.6	15 ± 11-	0.49 ± 0.29
Mudginberri	Oct 2003	20.8 ± 1.2	12.0 ± 2.7	19.7 ± 10.6	0.58 ± 0.26
Sandy	Oct 2002	7.3 ± 1.0	6.7 ± 2.1	-	0.91 ± 0.64
Sandy	Oct 2003	6.3 ± 1.0	12.1 ± 2.6	18.9 ± 10.4	1.91 ± 1.0

Fish

The 2000 and 2002 fish collections from Mudginberri Billabong and 2002 fish collection from Sandy Billabong were analysed for ^{226}Ra using the modified $BaSO_4$ method (Sill, 1987. Medley et al 2005). There is some variation of concentrations of ^{226}Ra within the fish collected but this is expected for a set of biological samples like this. There are a number of reasons for the variation, these include the uncertainty in the measurements of smaller samples of fish, because there is less material to analyse, different species of fish, differing diets, each fish has slightly different metabolism and therefore have different take up rates, the fish live in and move around different parts of the billabongs, moving up and down the creek systems and live in different locations at different parts of the year. The billabong does

not behave the same every year, for example, the last few years including and preceding the collections have been wetter than usual so that the water level would have been higher.

The scatter plot in Figure 5 illustrates the ^{226}Ra results (Appendix G) from the fish collections of 2000 and 2002, with two separate locations being collected in 2002. The results from the two collections from Mudginberri Billabong and the collection from Sandy Billabong appear to be of similar values. A 2003 Mudginberri fish collection analysis is not yet complete.

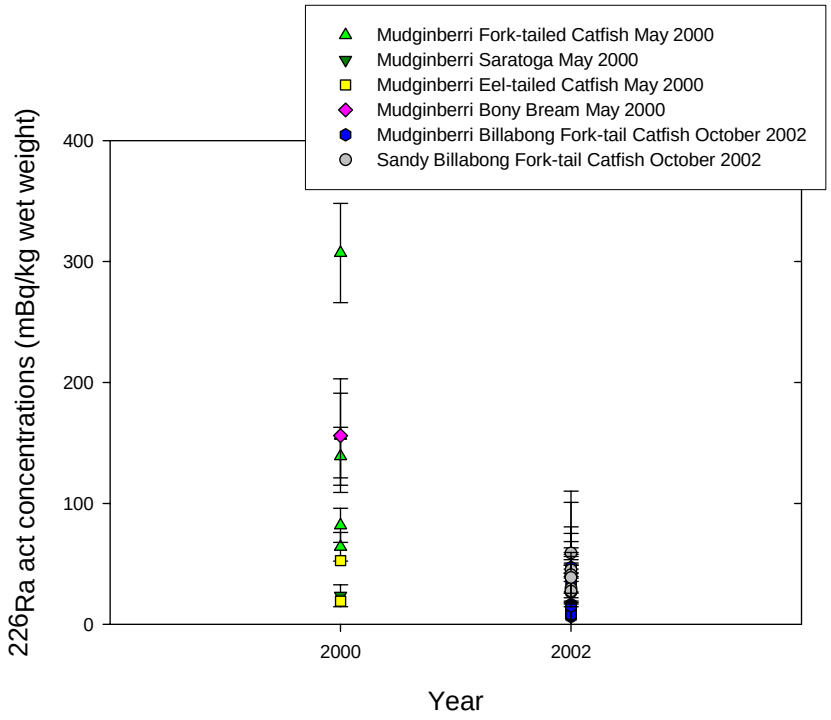

Figure 5 ^{226}Ra activity concentrations in fish from Mudginberri and Sandy Billabongs for year 2000 to 2002 (wet weight). Eel tailed catfish values are maximum values.

Samples of fish from 2000, 2002 and 2003 were sent to CDU (Appendix F) for ICPMS analysis. Samples from 2000 were also sent to NTEL (Appendix F) for ICPMS analysis.

Mussel physical parameters

Table 4 and Figure 9b show that the predominant age range for mussels collected (73%) was 2 to 6 years. The maximum ages and life span of riverine (lotic) mussels (V. angasi) are known to be much shorter than many billabong (lotic) populations in the ARR (C Humphrey, pers. obs.), possibly due to the less stable riverine environment. For example, greater wet season scouring of riverine channels (and dislodging of mussels), greater susceptibility to predation in the shallower dry season waters, and so forth. Table 4 also shows the relative frequency of mussels collected from each age class by collection date and over all collection dates.

Table 4 Relative frequencies p_i of live mussels collected from each age class, by collection site

Mussel Age	May 00	Oct 00	Sept 01	Oct 02	Oct 02	Oct 03	Oct 03	All
Site	Mudg	Mudg	Mudg	Mudg	Sandy	Mudg	Sandy	
η	58	37	80	103	77	111	101	567
Age 1	0.017		0.2	0.01		0.18	0.07	0.08
Age 2	0.14	0.35	0.26	0.08	0.06	0.22	0.08	0.16
Age 3	0.10	0.14	0.21	0.17	0.10	0.10	0.1	0.13
Age 4	0.26	0.19	0.15	0.23	0.12	0.14	0.09	0.16
Age 5	0.24	0.16	0.09	0.19	0.25	0.14	0.15	0.17
Age 6	0.12	0.10	0.03	0.08	0.10	0.10	0.24	0.11
Age 7	0.05	0.03	0.05	0.09	0.10	0.06	0.09	0.07
Age 8	0.02	0.03		0.07	0.16	0.02	0.13	0.06
Age 9	0.03		0.13	0.02	0.04	0.02	0.04	0.025
Age 10	0.017			0.04	0.03	0.01	0.01	0.02
Age 11				0.01	0.01	0.01		0.01
Age 12+				0.02	0.03	0.02	0.01	0.01

Table 5 displays the mean weights (dry) for each mussel age class for all collection dates with the wet dry ratio shown in Table 6. The relative frequencies were used to calculate the total activity (Table 9) from the average activity concentrations as shown in Table 9 and 7 using the following equation:

$$A_{tot} = m \cdot \sum_i C_i \cdot p_i \cdot r_i \qquad (1)$$

with:

m: total weight of ingested mussels [kg]

C_i: average activity concentration of i-year old mussel [Bq/kg]

p_i: proportion of mussel from each age class (table 5)

r_i: dry/wet weight ratio (table 7)

i: 0,1,2,3,4,5,6,7,10,11,12,13,14,16

Table 5 Mean and standard deviation of dry weight (g) for mussels collected from each age class, by collection date and over all collections. Standard deviation not indicated when $n = 1$.

Mussel Age	**May 00**	**Oct 00**	**Sept 01**	**Oct 02**	**Oct 02**	**Oct 03**	**Oct 03**
Site	**Mudg**	**Mudg**	**Mudg**	**Mudg**	**Sandy**	**Mudg**	**Sandy**
η	58	37	80	103	77	111	101
Age 1	0.14		0.85 ± 0.32	0.45		0.28 ± 0.14	0.22 ± 0.09
Age 2	0.22 ± 0.04	1.14 ± 0.26	1.10 ± 0.78	0.66 ± 0.15	0.71 ± 0.14	0.70 ± 0.18	0.32 ± 0.07
Age 3	0.24 ± 0.06	1.11 ± 0.32	1.09 ± 0.35	0.92 ±0.16	0.70 ± 0.27	0.86 ± 0.11	0.47 ± 0.14
Age 4	0.32 ± 0.13	1.45 ± 0.26	1.11 ± 0.53	1.07 ± 0.25	0.73 ± 0.17	0.95 ± 0.18	0.49 ± 0.15
Age 5	0.41 ± 0.15	1.45 ± 0.34	1.24 ± 0.36	1.13 ± 0.26	0.76 ± 0.21	1.03 ± 0.28	0.70 ± 0.40
Age 6	0.48 ± 0.12	1.51 ± 0.34	0.86 ± 0.04	1.14 ± 0.25	0.98 ± 0.36	1.13 ± 0.19	0.75 ± 0.19
Age 7	0.58 ± 0.24	1.23	1.22 ± 0.31	1.27 ± 0.21	0.99 ± 0.16	1.11 ± 0.36	0.74 ± 0.15
Age 8	0.49	2.78	0.98	1.21 ± 0.36	0.99 ± 0.18	1.55 ± 0.50	0.79 ± 0.18
Age 9	0.62 ± 0.11			1.46 ± 0.44	1.14 ± 0.16	0.83 ± 0.13	0.75 ± 0.17
Age 10	0.84			1.23 ±0.17	0.90 ± 0.50	1.17	0.72
Age 11				1.27	1.09	1.11	
Age 12				1.28 ± 0.30	0.89 ± 0.44		
Age 13							0.57
Age 14						1.03	
Age 16						0.83	

Table 6 Mean and standard deviation of dry/wet weight ratios r_i for mussels collected from each age class, by collection date and over all collections. Standard deviation not indicated when $n = 1$.

Mussel Age	**May 00**	**Oct 00**	**Sept 01**	**Oct 02**	**Oct 02**	**Oct 03**	**Oct 03**
Site	Mudg	Mudg	Mudg	Mudg	Sandy	Mudg	Sandy
η	58	37	80	103	77	111	101
Age 1	0.081		0.11 ± 0.02	0.35		0.15 ±0.02	0.13 ± 0.01
Age 2	0.09 ± 0.01	0.11 ± 0.02	0.12 ± 0.04	0.26 ± 0.04	0.11 ± 0.01	0.15 ±0.01	0.13 ± 0.02
Age 3	0.09 ± 0.02	0.11 ± 0.02	0.12 ± 0.02	0.23 ± 0.03	0.11 ± 0.03	0.16 ± 0.02	0.15 ± 0.02
Age 4	0.09 ± 0.01	0.13 ± 0.07	0.12 ± 0.01	0.2 ± 0.04	0.10 ± 0.02	0.16 ± 0.02	0.14 ± 0.01
Age 5	0.10± 0.02	0.12 ± 0.02	0.13 ± 0.02	0.21 ± 0.04	0.09 ± 0.02	0.16± 0.03	0.14 ± 0.02
Age 6	0.10 ± 0.02	0.12 ± 0.02	0.11 ± 0.02	0.21 ± 0.03	0.11 ± 0.02	0.16 ± 0.02	0.15 ± 0.02
Age 7	0.10 ± 0.01	0.10	0.13 ± 0.01	0.19 ± 0.03	0.10 ± 0.01	0.14 ± 0.04	0.14 ± 0.01
Age 8	0.14	0.15	0.09	0.18 ± 0.05	0.10 ± 0.02	0.16 ±0.02	0.14 ± 0.02
Age 9	0.11 ± 0.02			0.13 ± 0.02	0.12 ± 0.01	0.16 ± 0.02	0.12 ± 0.03
Age 10	0.12			0.21 ± 0.03	0.07 ± 0.00	0.15	0.12
Age 11				0.15	0.08	0.15	
Age 12				0.21 ± 0.05	0.08 ± 0.03		
Age 13							0.11
Age 14						0.14	
Age 16						0.14	

Radionuclides

The ^{226}Ra activity concentration results from Mudginberri Billabong October 2000, September 2001 October 2002 and October 2003 mussel collections are lower for the same age group of mussels that were collected in May 1983, February 1986 and May 2000 (Table 7). The latter four sets of mussels were taken from the upstream end or inlet of the billabong, whereas the earlier collections were either from the eastern side of the billabong about halfway down (1983, 1986), or at the outlet (May 2000) as shown in Figure 4.

Table 7 ^{226}Ra activity concentration results for mussel collections Mudginberri Billabong and Sandy Billabong (mBq/g dry weight)

Age	May 83 Mudg	Feb 86 Mudg	May 00 Mudg	Oct 00 Mudg	Sept 01 Mudg	Oct 02 Mudg	Oct 03 Mudg	Oct 02 Sandy	Oct 03 Sandy
1					225		273		
2	1080	470	900	289	414	379	423	136	287
3	1200	–	1340	404	469	530	561	207	291
4	–	1150	1250	441	660	724	633	292	347
5	1700	1600	1200	601	660	759	623	367	418
6	2100	1500	1740	724		1027	937	389	473
7	2900	1870	1870		980	896	1002	478	653
8						1312	1299	520	725
9								483	748
10						1733			
12						1921			

The higher ^{226}Ra activity concentrations for mussels collected in May 2000 (Figure 6) may be explained partly by the sediment distribution in the billabong. The billabong sediment at the outlet would be expected to be finer than at the inlet proper and so have higher natural radium concentrations and therefore slightly higher radium results (Table 3) although there are no results for May 2000, whereas at the billabong inlet, the sediments are larger coarser grained sand particles.

As can be seen, results for ^{226}Ra activity concentration, ^{226}Ra load (Figure 6), ^{228}Ra and ^{228}Th activity concentrations (Figure 7) and ^{228}Th/^{228}Ra activity ratio (Figure 8) are strongly age dependent. In particular, ^{226}Ra activity concentrations and load per mussel increase with mussel age because the biological half-life of radium in mussels is long, radium is excreted at a lower rate than which it is taken up, thereby accumulating in mussel flesh.

The ^{228}Ra/^{226}Ra ratio (Figure 8) decreases with mussel age due to faster decay of the ^{228}Ra isotope (half-life of 5.75 years) compared to the ^{226}Ra isotope (half-life of 1600 years), following uptake of radium by the mussel. The ^{228}Th/^{228}Ra activity ratio increases with mussel age because of ingrowth of the ^{228}Th daughter (half-life = 1.91 years) following uptake of ^{228}Ra by the mussel. Hence when comparing results, it is important to compare those for mussels of the same age.

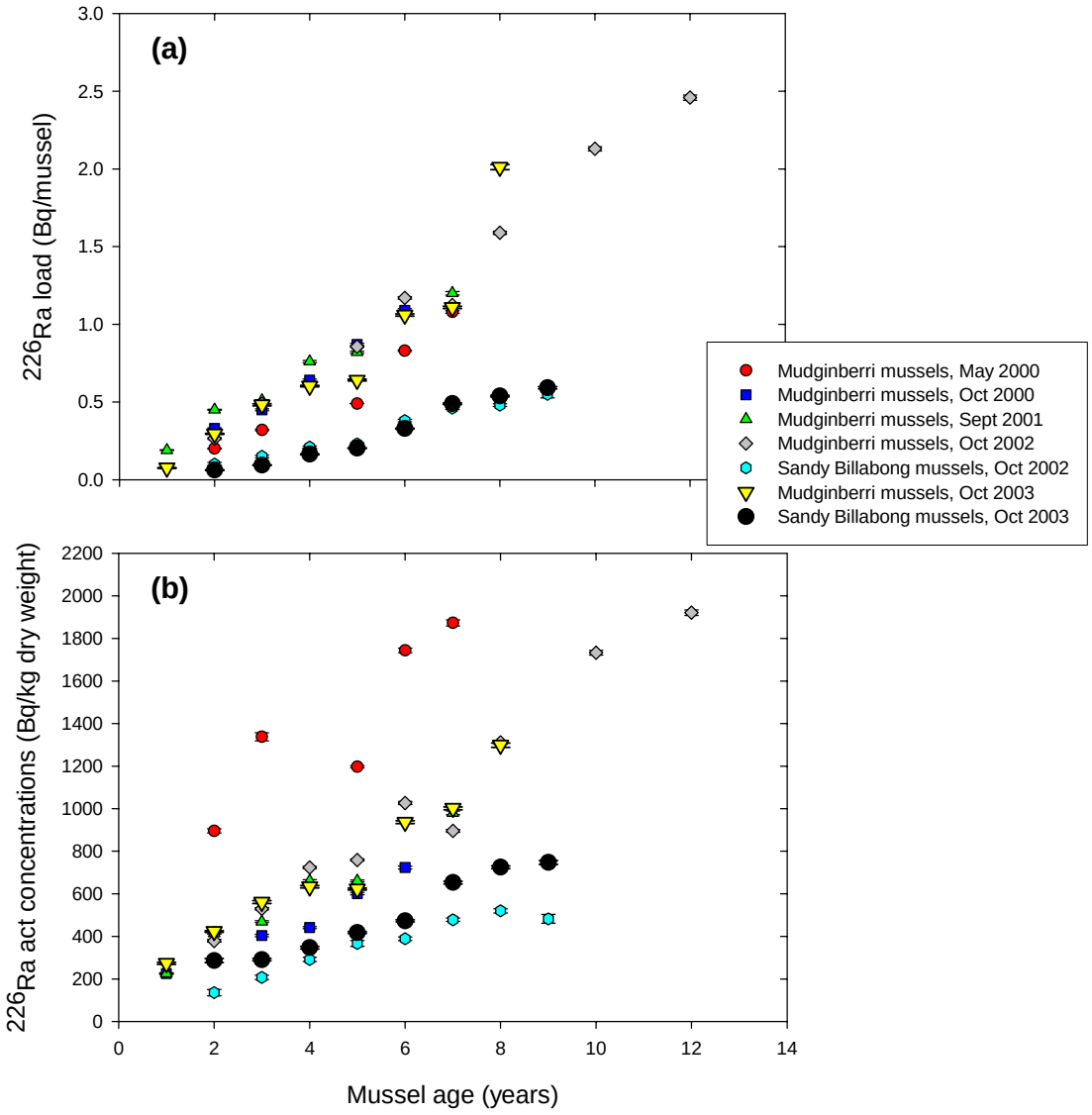

Figure 6 ^{226}Ra results for mussel age groups from Mudginberri Billabong May 2000, October 2000, September 2001 and Mudginberri and Sandy Billabong (control site) 2002 and 2003 collections, analysed by gamma spectrometry. (a) ^{226}Ra activity load and, (b) ^{226}Ra activity concentration.

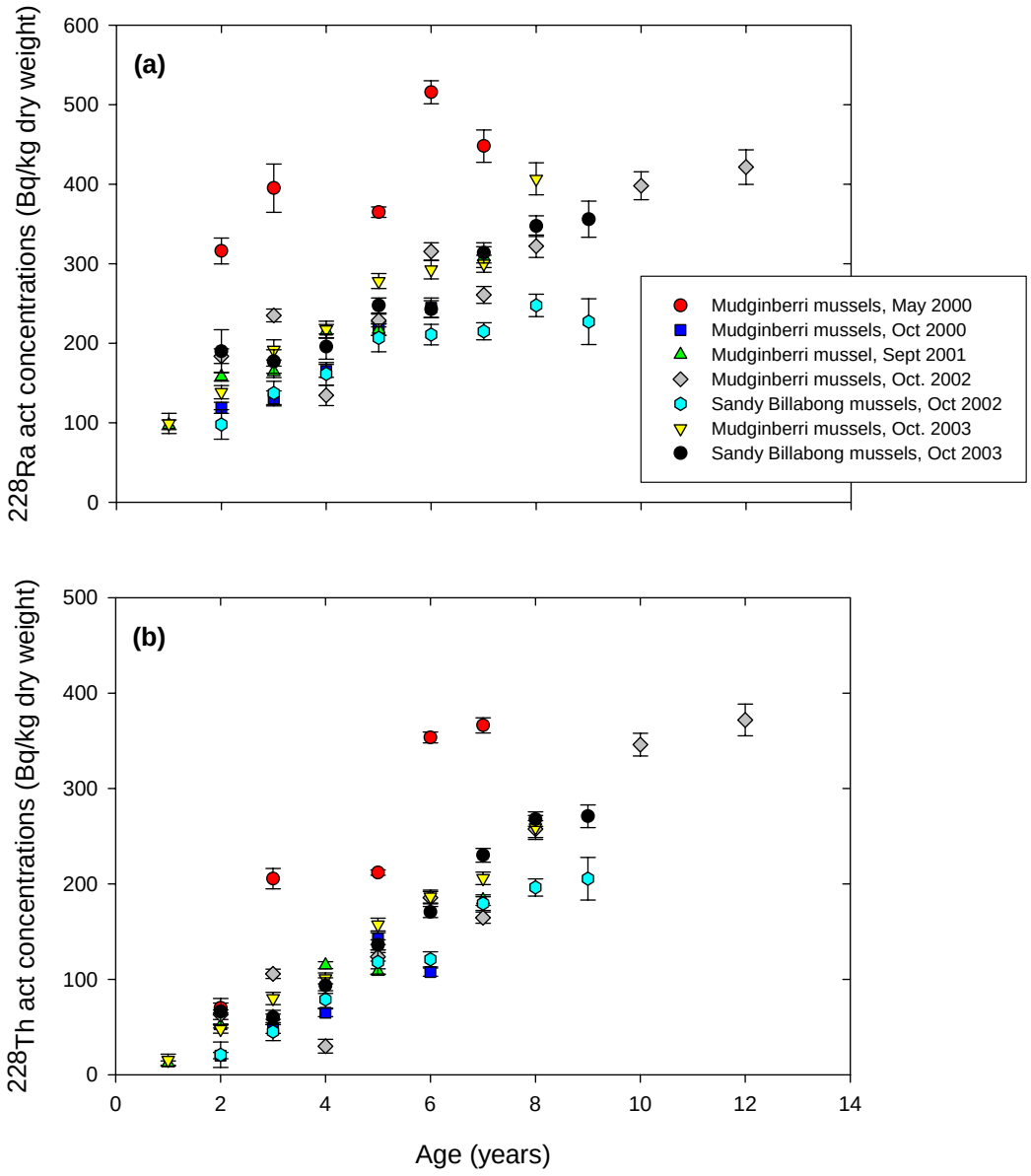

Figure 7 ^{228}Ra and ^{228}Th results for mussel age groups from Mudginberri Billabong May 2000, October 2000, September 2001 and Mudginberri and Sandy Billabong (control site)2002 and 2003 collections, analysed by gamma spectrometry. (a) ^{228}Ra activity concentration and, (b) ^{228}Th activity concentration

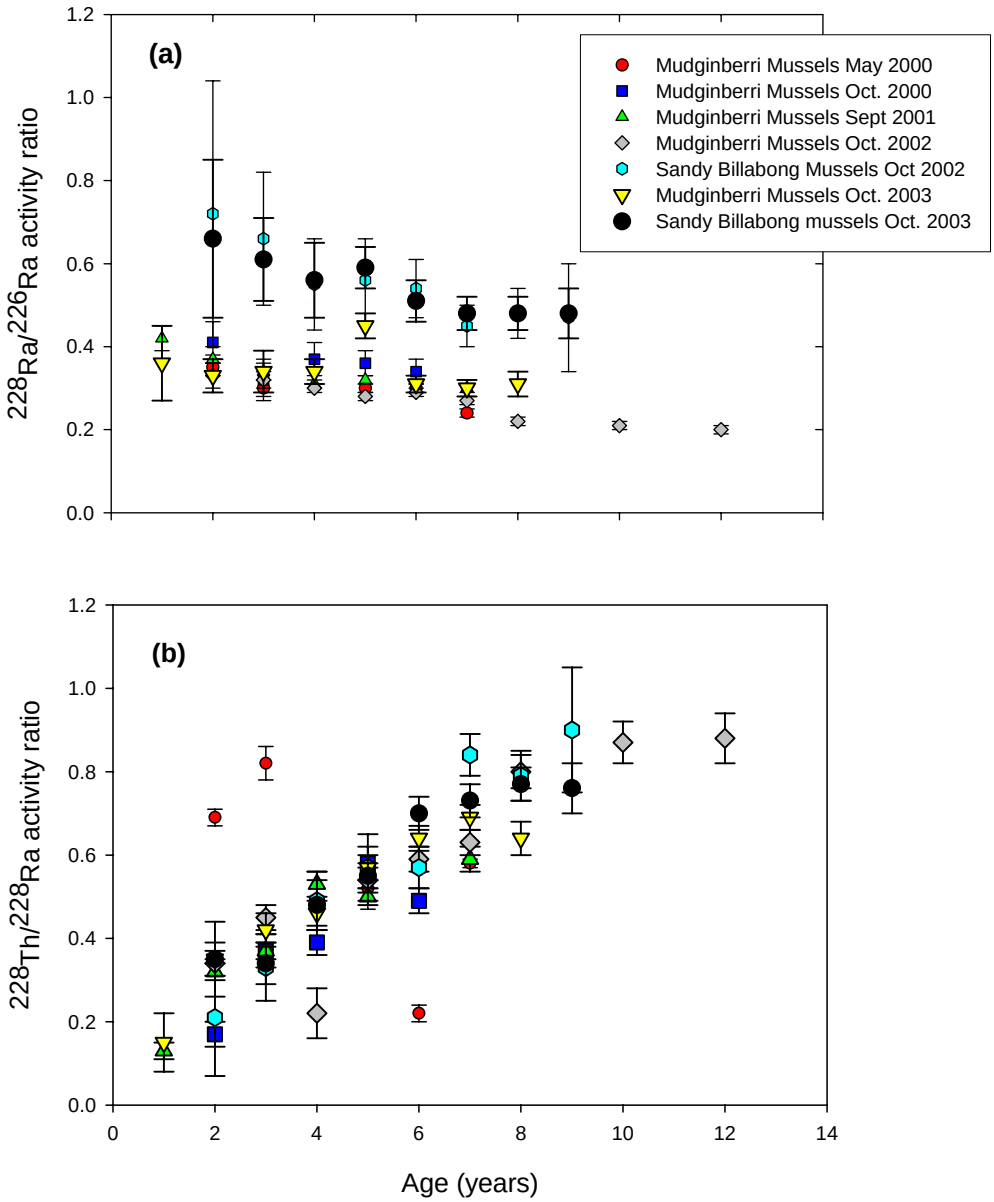

Figure 8 Activity ratios for mussel age groups from Mudginberri Billabong May 2000, October 2000, September 2001 and Mudginberri and Sandy Billabong (control site) 2002 and 2003 collections, analysed by gamma spectrometry. (a) $^{228}Ra/^{226}Ra$ activity ratio and, (b) $^{228}Th/^{228}Ra$ activity ratio

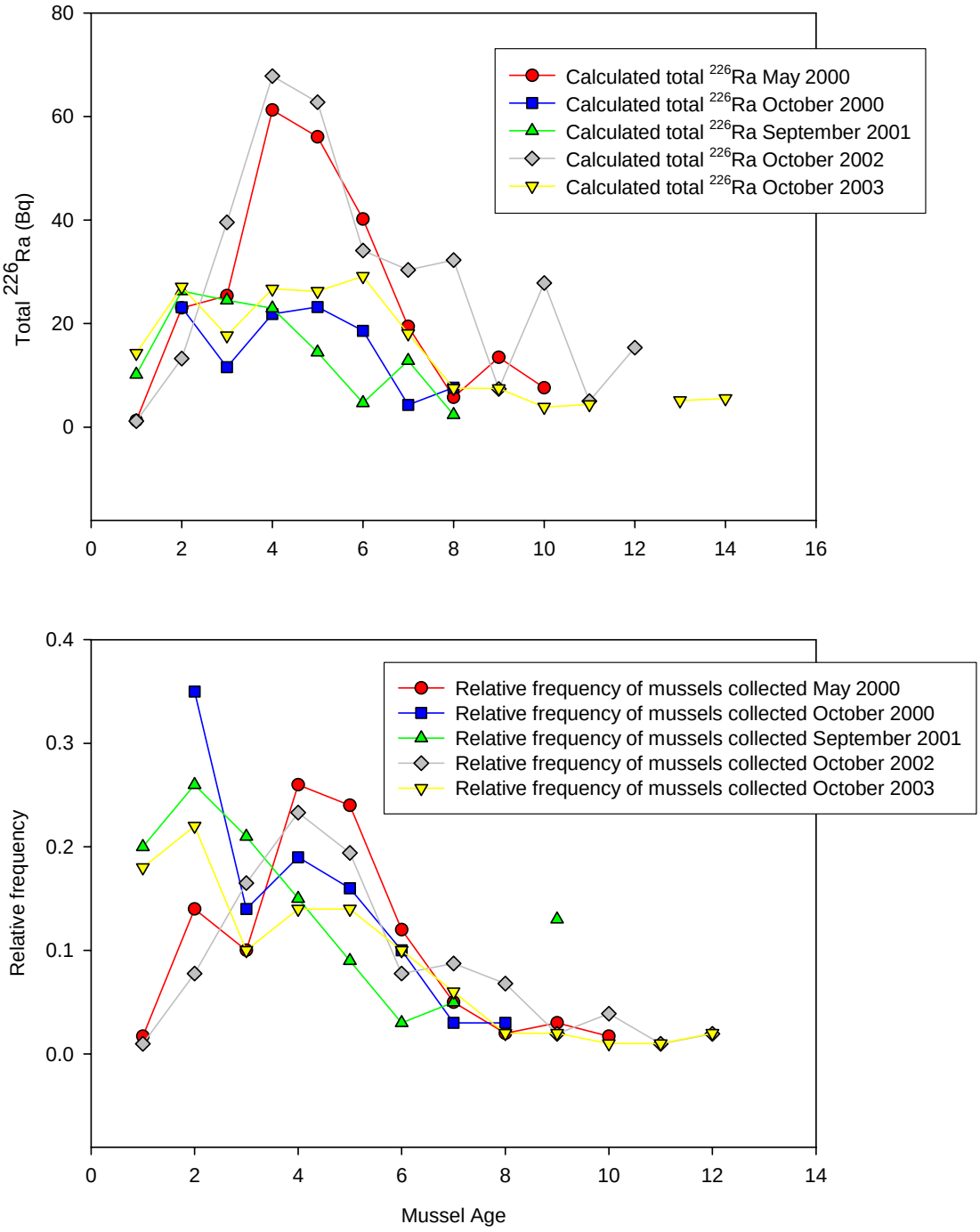

Figure 9 Mudginberri Billabong May 2000, October 2000, September 2001 October 2002 and October 2003 collections, (a) Calculated total Bq for a diet of 2kg of wet mussels using dry weights and proportions and, (b) Relative frequencies of live mussels collected from each age class

Table 8 ^{210}Pb activity concentration results for mussel collections Mudginberri Billabong and Sandy Billabong (mBq/g dry weight)

Age	May 00 Mudg	Oct 00 Mudg	Sept 01 Mudg	Oct 02 Mudg	Oct 03 Mudg	Oct 02 Sandy	Oct 03 Sandy
1			86		27		
2	475	39	104	50	63	15	79
3	326	92	113	109	83	71	96
4		126	221	104	102	95	84
5	601	152	259	123	153	105	120
6	1055	169		139	148	72	145
7	1050		429	106	157	120	169
8				169	362	177	201
9						164	352
10				443			
12				257			

There is some variation of concentrations within each age group but this is expected. There are a number of reasons for the variation, much the same as the fish samples already discussed, these include the uncertainty in the measurements of young mussels, because there is less material to analyse, each mussel has slightly different metabolism and therefore have different take up rates, the mussels were not taken from exactly the same part of the billabong or at the same time of year, the billabong does not behave the same every year, for example, some years have been wetter than others so that the water level would have been higher.

There is also an apparent drop in concentrations, between May 2000 and October 2000, for the sets of mussels that were collected at different times of the year. This is contrary to the increase in mussel tissue mass that mussels have in May, although more data needs to be collected to substantiate this.

From the data presented in Table 7 there is no obvious trend for ^{226}Ra concentrations, in mussels of the same age and location, to be increasing with time. In the case of the two year old mussels, the year 2000 result is in between the results for 1983 and 1986, and so there is no evidence of a significant change between the 1980s and 2000.

Figure 9 shows total ^{226}Ra activity concentrations for Mudginberri mussels to be higher for 4 and 5 year old mussels from the May 2000 and October 2002 collections. The relative frequency of these age groups of mussels (Figure 9) is high for these two collections (Table 5), whereas in other collections the relative frequency of younger mussels is much more pronounced. The overestimate of 4 and 5 year old mussels have artificially inflated the effective dose rates. The combination of these two variables have made the effective dose calculations higher, relative to the other collections in Table 9, with 4 and 5 year old mussels accounting for 46% of ^{226}Ra dose activity and 40 % of ^{210}Pb dose activity for the May 2000 and 39% of the ^{226}Ra dose activity and 37% of the ^{210}Pb dose activity for the October 2002 collection. This has led to a higher committed effective dose (Table 11) for a 10-year old child for these two collections.

Table 9 Calculated activity concentration of ^{226}Ra and ^{210}Pb for a diet of 2kg (wet wt) of mussels using dry weights (Table 6) and proportions (Table 7) from Mudginberri Billabong 2000–2003 and Sandy Billabong 2002–2003 mussel collections

Mussel Age	Total ^{226}Ra (Bq) May 2000	Total ^{210}Pb (Bq) May 2000	Total ^{226}Ra (Bq) Oct 2000	Total ^{210}Pb (Bq) Oct 2000	Total ^{226}Ra (Bq) Sept 2001	Total ^{210}Pb (Bq) Sept 2001	Total ^{226}Ra (Bq) Oct 2002	Total ^{210}Pb (Bq) Oct 2002	Total ^{226}Ra (Bq) Oct 2003	Total ^{210}Pb (Bq) Oct 2003	Total ^{226}Ra (Bq) Oct 2002	Total ^{210}Pb (Bq) Oct 2002	Total ^{226}Ra (Bq) Oct 2003	Total ^{210}Pb (Bq) Oct 2003
	Mudg	**Mudg**	**Mudg**	**Mudg**	**Mudg**	**Mudg**	**Mudg**	**Mud**	**Mudg**	**Mudg**	**Sandy**	**Sandy**	**Sandy**	**Sandy**
Age 1	1.27	0.25			10.19	3.87	1.16	0.10	14.30	1.43			1.86	0.51
Age 2	23.04	12.22	23.15	3.14	26.32	6.59	13.26	1.74	27.09	4.03	1.55	0.17	3.42	1.13
Age 3	25.39	6.18	11.57	2.65	24.51	5.93	39.56	8.15	17.69	2.61	3.70	1.26	7.12	1.72
Age 4	61.26	24.46	21.87	6.25	22.98	7.68	67.81	9.76	26.70	4.31	6.18	2.02	7.94	2.28
Age 5	56.07	28.15	23.21	5.86	14.46	5.67	62.77	10.16	26.25	6.43	13.55	3.86	22.08	6.79
Age 6	40.19	24.32	18.62	4.34	4.70	1.94	34.13	4.63	29.15	4.61	9.51	1.76	51.95	13.49
Age 7	19.45	10.91	4.31	1.04	12.84	5.62	30.36	3.58	18.07	2.83	12.04	3.01	21.35	5.91
Age 8	5.76	6.12	7.63	1.83	2.40	1.08	32.28	4.17	7.53	2.10	18.98	6.46	34.36	16.15
Age 9	13.49	11.76					7.39	1.23	7.46	1.73	5.24	1.78	13.65	4.93
Age 10	7.60	7.12					27.86	7.12	3.87	0.920	3.42	1.07	2.87	1.05
Age 11							5.03	0.85	4.38	1.06	2.28	0.72		
Age 12							15.37	2.06			3.95	1.26		
Age 13													2.84	1.076
Age 14									5.14	1.29				
Age 16									5.54	1.41				
Total	**254**	**131**	**110**	**25**	**118**	**38**	**337**	**54**	**193**	**35**	**80**	**23**	**169**	**55**

Mussels were also collected from Sandy Billabong for the first time in October 2002 and again in October 2003 and used as a control sample group. The ^{226}Ra and ^{210}Pb results (Table 7 & 8) for the Sandy Billabong mussels are lower than the mussels collected from Mudginberri Billabong. This was expected because of the apparent lower concentrations of radium in the sediment (Table 3). There is only one ^{226}Ra water result from Sandy Billabong (Table 2) to compare to the Mudginberri Billabong results and as more results are accumulated a more comprehensive comparison will be possible.

Conclusions

Table 10 shows committed effective doses[1], which have been calculated using the data from each billabong collection and assuming that a 10-year old child eats 2 kg (wet weight) of flesh from mussels per year. These doses have been calculated using the equation:

$$CED = D_{Ra} + D_{Pb} \quad (2)$$

and

$$D = A \times DCF \quad (3)$$

where :

D_{Ra}: calculated dose from ^{226}Ra, [μSv]

D_{Pb}: calculated dose from ^{210}Pb, [μSv]

A: Activity [Bq]

DCF: Dose conversion factor, μSv/Bq (ICRP 72, 1996).

Table 10 Committed effective doses calculated for a 10-year old child who eats 40 kg of fish flesh (wet). Based on average concentrations of ^{226}Ra in fish samples from Mudginberri Billabong 2000 & 2002 and Sandy Billabong 2002. Dose conversion factor from ICRP Report No 72

Collection	Committed effective dose (mSv)
Mudginberri August 1985	0.00328
Mudginberri May 2000	0.00295
Mudginberri October 2002	0.00131
Sandy October 2002	0.00123

Table 10 shows average committed effective doses, which have been calculated using the data for several fish species from each billabong collection and includes a collection made by ***eriss*** in August 1985 from Mudginberri Billabong. Assuming that a 10-year old child eats 40 kg (wet weight) of fish flesh per year, the committed effective doses are two orders of magnitude less than the freshwater mussel contribution, bearing in mind that fish organs were not included in the calculations. These doses have been calculated using equation 2 and 3.

Using the age, weight and proportional information from Tables 4, 5 and 6 a hypothetical bush food collection of 2 kg of mussels (wet weight) was used to calculate and estimate the committed effective dose for a 10-year-old child living at Mudginberri Billabong (Table 11).

[1] Committed effective dose is a technical term. It indicates that the dose has been calculated in a way that accounts for the long-term nature of the dose (i.e. the person is "committed" to receiving the dose over several years) as well as the type of radiation involved and the type of tissues irradiated.

The figure of 0.270 mSv in Table 12 is an average dose per year a ten year-old child may be expected to receive from eating mussels from Mudginberri Billabong. This dose was calculated using the data collected from the last five mussel collections and may be considered a reasonable estimation as it contains mussels collected from both the outlet and inlet of the billabong. The same calculations were performed using the data collected from the 2002 and 2003 mussel collections at Sandy Billabong and an average figure of 0.074 mSv was derived from the control site. The higher committed effective dose value calculated for Mudginberri Billabong may be a result of the higher naturally occurring backgrounds of ^{226}Ra for water and sediments as shown in Tables 2 and 3. These higher values may be a result of the mineralised nature of the Magela Creek catchment area contributing to higher ^{226}Ra values in water, sediment and mussels in Mudginberri Billabong. Particle size and mineralogical differences in the billabong sediments may also play a role, with Mudginberri sediments being finer where the mussels are collected and hence having higher ^{226}Ra values. Higher ^{226}Ra activity concentration per gram of mussel for same aged mussels from Mudginberri Billabong (Figure 6b), resulting in higher concentrations would also increase the committed effective dose via human consumption.

Table 11 Committed effective doses calculated for a 10-year old child who eats 2 kg of mussel flesh (wet). Based on average concentrations of ^{226}Ra and ^{210}Pb in mussel samples from Mudginberri Billabong 2000 –2003 and Sandy Billabong 2002-2003. Dose conversion factor from ICRP Report No 72. Proportions of mussels used taken from Table 5.

Collection	Committed effective dose (mSv)
Mudginberri May 2000	0.453
Mudginberri October 2000	0.136
Mudginberri September 2001	0.168
Mudginberri October 2002	0.371
Sandy October 2002	0.044
Mudginberri October 2003	0.221
Sandy October 2003	0.105

Early studies (Jeffree and Simpson, 1986) have shown that the presence of calcium in water reduces the rate of radium uptake and is inversely proportional to radium levels present in freshwater mussels in the region. The ICPMS results (appendix B, D, I, K, P and T) show that there is more calcium in Sandy billabong water, sediments and mussels in the 2002 and 2003 collections than the respective Mudginberri samples during the same period. This may also explain the higher levels of ^{226}Ra in Mudginberri mussels when compared to Sandy Billabong mussels.

Table 12 Average committed effective doses calculated for a 10-year old child who eats 2 kg of mussel flesh, based upon average concentrations of ^{226}Ra and ^{210}Pb from Mudginberri mussel collections (2000-2003) and Sandy mussel collections (2002-2003). Relative frequencies of mussels used taken from Table 4.

Sample	Committed effective dose (mSv)
Average all collections from Mudginberri Billabong	0.270
Average all collections from Sandy Billabong	0.074

Table 13 also provides historical evidence supporting the hypothesis that radium levels have not increased downstream of Ranger Uranium Mine. The samples in Table 13 were collected by several organisations (Northern Territory Museum of Arts and Sciences 1976-77, Ranger Uranium Mine 1980-81 and ***eriss*** 1982 and 1983) and analysed as age composites in 1983 by ***eriss*** at their Jabiru laboratory. It is evident that any increase in radium during the 1970s and early 1980s was regional in nature and of natural origins. It can also be seen from data presented in Table 7 that there has been no apparent increase of radium in mussels over time at Mudginberri Billabong downstream of Ranger Uranium Mine from 1983 through to 2003.

Table 13 Historical ^{226}Ra activity concentrations for mussels, both upstream and downstream of Ranger Uranium Mine (ARRRI Research Report, 1983-84)

Collection	Location	^{226}Ra	$^{228}Ra/^{226}Ra$
1983	Bowerbird B/bong	3440	0.43
1976	Georgetown B/bong	2250	0.263
1977	Georgetown B/bong	1040	0.231
1980	Georgetown B/bong	1730	0.206
1981	Georgetown B/bong	1570	0.235
1982	Georgetown B/bong	2140	0.235
1983	Georgetown B/bong	2180	0.216
1983	Mudginberri B/bong	2560	0.26

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Appendices

Appendix A Physical data for fish collections at Mudginberri Billabong

Table A1 Physical data for May 2000 fish collection

***eriss*_id**	**Species**	**Wt. (kg)**	**Length (mm)**
MI0008	ET 2	1.180	345
MI0009	ET 5	0.595	380
MI0011	ET 7	0.695	395
MI0002	FT 2	1.720	485
MI0003	FT 3	1.375	455
MI0004	FT 4	1.140	410
MI0005	FT 5	1.500	475
Mi0006	FT 6	0.990	425
MI0007	SA 1	2.095	605
MI0012	BB 1	0.275	300

Table A2 Physical data for May 2000 fish collection *eriss* Environmental Chemistry metal analysis

***eriss*_id**	**Species**	**Sample**	**Wet weight (g)**
MI0010	ET 6	ET6 Flesh	11.2706
MI0010	ET 6	ET6 Kidney	3.0231
MI0010	ET 6	ET6 Liver	0.9433
N/A	ET 9	ET9 Flesh	10.6801
N/A	ET 9	ET9 Kidney	3.2060
N/A	ET 9	ET9 Liver	1.8801
N/A	FT 1	FT1 Flesh	10.3662
N/A	FT 1	FT1 Kidney	5.6747
N/A	FT 1	FT1 Liver	4.2916
N/A	FT 10	FT10 Flesh	4.9437
N/A	FT 10	FT10 Kidney	3.0612
N/A	FT 10	FT10 Liver	2.1543

Table A3 Physical data for October 2002 Mudginberri fish collection

*eriss*_id	Species	Whole fish length (mm)	Whole fish wet wt (g)	Wet wt flesh (g)	Dry wt (g)	Dry: Wet
MI02002	FT	334	363	53.29	10.41	0.195
MI02003	FT	377	627	94.87	19.75	0.208
MI02004	FT	336	420	57.96	10.98	0.189
MI02005	FT	417	695	75.56	14	0.185
MI02006	FT	276	273	32.6	6.45	0.198
MI02007	FT	325	372	51.57	10.2	0.198
MI02008	FT	340	401	46.44	9.09	0.196
MI02009	FT	372	466	72.55	14.56	0.201
MI02010	FT	375	574	74.46	14.63	0.196
MI02011	FT	380	627	81.47	15.97	0.196
MI02012	FT	341	443	54.93	11.25	0.205
MI02013	FT	385	567	70.13	13.42	0.191
MI02014	FT	346	458	65.87	13.03	0.198
MI02015	FT	390	704	90.12	17.78	0.197
MI02016	FT	329	412	77.79	13.83	0.178
MI02017	FT	283	230	15.08	2.69	0.178
MI02018	FT	294	254	28.7	4.99	0.174

Table A4 Physical data for September 2003 Mudginberri fish collection

*eriss*_id	Species	Tissue	Dry (g)	Wet (g)	Dry:wet
MI03112	ET	Flesh	127	533	0.238461
MI03113	ET	Kidney	4.3	24	0.176701
MI03114	ET	Liver	2.6	12	0.209842
MI03115	ET	Guts	6.5	26	0.254073
MI03116	FT	Flesh	97	474	0.206222
MI03117	FT	Kidney	5.6	30	0.18774
MI03118	FT	Liver	4.6	17	0.263932
MI03119	FT	Guts	24	68	0.359128
MI03120	SA	Flesh	158	534	0.296133
MI03121	SA	Kidney	1.3	5.6	0.230503
MI03122	SA	Liver	3.9	18	0.22057
MI03123	SA	Guts	21	734	0.285347
MI03124	BB	Flesh	206	642	0.321798
MI03125	BB	Liver	0.5	2	0.246994
MI03126	BB	Kidney	9.1	28	0.327267
MI03127	BB	Guts	33	69	0.481581
MI03128	TP	Flesh	314	916	0.342766
MI03129	TP	Liver	3.9	9	0.426822
MI03130	TP	Guts	33	119	0.274324

ET = Eel Tail Catfish, FT = Fork Tail Catfish, SA = Saratoga, BB = Bony Bream, TP = Tarpon

Appendix B Mudginberri Billabong ICPMS results for water (ppb)

Table B1 Semi-quantative scan of MI0001 Mudginberri Billabong water May 2000

Li	**Be**	**Na**	**Mg**	**Al**	**Si**	**P**	**Cl**	**K**	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**
0.65	0.043	2411	1291	11.3	2190	6.26	15506	482	1043	0.95	0.71	0.12	0.44	9.9	151.	0.09	1.2	1.01	7.68
Ga	**As**	**Se**	**Br**	**Rb**	**Sr**	**Y**	**Zr**	**Mo**	**Rh**	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	**I**	**Cs**	**Ba**
0.01	0.17	0.14	32.3	1.036	5.638	0.02	0.065	0.128	0.001	0.003	0.006	0.002	0.009	0.444	0.026	0.012	0.805	0.017	6.269
La	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Dy**	**Ho**	**Er**	**Hf**	**Re**	**Pt**	**Tl**	**Pb**	**Bi**	**Th**	**U**		
0.018	0.048	0.007	0.026	0.002	0.001	0.003	0.001	0.001	0.001	0.001	0.01	0.009	0.003	0.498	0.019	0.048	0.116		

Table B2 ICPMS results for Mudginberri Billabong water, May 2000

***eriss*_id**	**Species**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**Al**	**Na**	**Cr**	**Co**	**Ni**
MI0001	Water (F)	1100		8.8		<DL		0.46	0.05		114	0.81	6.6					
MI0001	Water (R)	7.45*		0.618*	1	0.004*	03.37*	0.69*	0.09*	0.483	248*	0.79*	1.29	11.4	2412	0.437	0.08*	0.79*

Table B3 ICPMS results for Mudginberri Billabong water, September 2001

***eriss*_id**	**Species**	**Mg**	**Mn**	**U**	**Fe**	**Cu**	**Zn**	**Pb**
MI0111	Water (F)	1030	6.6	0.02	41	0.79	15.0	0.18

Table B4 ICPMS results for Mudginberri Billabong water, October 2002

***eriss*_id**	**Species**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**S**	**Th**
MI02020	Water (F)	1070	510	0.960	6.27	0.455	2.51	0.112	0.028	236.0	25.4	0.682	28.300	<	<

Table B5 ICPMS results for Mudginberri Billabong water, 2003

***eriss*_id**	**Species**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**S**	**Na**	**As**	**Se**	**V**	**Th**
MI03131	Water (F)	932	580	1.13	3.24	<	1.72	0.491	0.027	176	37.1	0.971	50.6	<	2060	0.123	<	<	<
MI03132	Water (F)	1040	764	0.474	3.99	<	1.89	0.353	0.027	188	67.3	1.50	93.8	<	2220	0.124	<	0.211	<

Appendix C Alpha spectrometry results for Mudginberri Billabong water

Table C1 ^{226}Ra and ^{210}Po in Mudginberri water (filtrate) May 2000 (mBq/L)

***eriss*_ID**	**^{226}Ra**	**^{210}Po**
MI0001	2.87 ± 0.30	1.54 ± 0.18
MI0001	4.78 ± 0.71	

Table C2 ^{226}Ra and ^{210}Po in Mudginberri water (residue) May 2000 (mBq/kg)

***eriss*_ID**	**^{226}Ra**	**^{210}P**
MI0001	1.33 ± 0.16	3.5 ± 0.38

Table C3 ^{226}Ra in Mudginberri water (filtrate) October 2000 (mBq/L)

***eriss*_ID**	**^{226}Ra**
MI0072	1.06 ± 0.24
MI0072	1.35 ± 0.26
MI0072	1.10 ± 0.49

Table C4 ^{226}Ra in Mudginberri water (residue) October 2000 (mBq/kg)

***eriss*_ID**	**^{226}Ra**
MI0072	2.84 ± 0.83
MI0072	2.12 ± 0.47

Table C5 ^{210}Po in Mudginberri water (filtrate) September 2001 (mBq/L)

***eriss*_ID**	**^{210}Po**
MI0111	0.361 ± 0.126

Table C6 ^{226}Ra and ^{210}Po in Mudginberri water (filtrate) October 2002 (mBq/L)

***eriss*_ID**	**^{226}Ra**	**^{210}Po**
MI02001		0.647 ± 0.06
MI02020	2.1 ± 0.24	

Table C7 ^{226}Ra in Mudginberri water (residue) October 2002 (mBq/kg)

***eriss*_ID**	**^{226}Ra**
MI02020	0.72 ± 0.25

Appendix D ICPMS results for Mudginberri Billabong sediment (ppm dry weight)

Table D1 ICPMS results for Mudginberri Billabong sediment, October 2002

***eriss*_id**	**Species**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**S**	**Th**
MI02019	Sediment	171.0	244	44.0	10.1	0.028	10.70	1.73	0.408	233	4550	2.68	3.74	178.0	1.30

Notes: nc: not certified; nr: no result; <: less than reporting limit

Table D2 ICPMS results for Mudginberri Billabong sediment, October 2003

***eriss*_id**	**Species**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba** [1]	**Pb**	**U** [1]	**K**	**Fe**	**Cu**	**Zn**	**Al**	**S**	**Na**	**P**	**As**	**Se**	**Th** [1]
MI03133	Sediment	9240	144	523	69.0	0.945	48.0	46.6	1.03	2630	19700	6.79	71.2	30900	88.3	171	390	0.290	4.26	5.19

*: National Research Council Canada reference sediment; <: Less than detection limit; >: over range; nc: not certified; (): information value only

1 The digestion performance could not be verified for Ba, Th and U as reference materials certified for these elements were unavailable.

Appendix E ^{226}Ra and ^{228}Ra/^{226}Ra ratios gamma spectrometry results for Mudginberri Billabong sediments (Bq/kg dry weight)

Table E1 ^{26}Ra and ^{228}Ra/^{226}Ra ratios gamma spectrometry results for Mudginberri Billabong sediments

Collection	^{226}Ra	^{228}Ra	^{228}Ra/^{226}Ra ratio	^{228}Th	^{210}Pb	^{40}K
October 2000	11 ± 1	6.6 ± 1.9	0.60 ± 0.35	9.1± 0.96		
September 2001	12 ± 1	16.9 ± 1.7	1.38 ± 0.18	14.2 ± 0.7	13 ± 7.2	218 ± 11
October 2002	19 ± 1	9.3 ± 2.6	0.49 ± 0.29		21 ± 10.1	15 ± 11
October 2003	21 ± 1	12 ± 3	0.58 ± 0.26	12 ± 2	26 ± 6	20 ± 11

Appendix F Mudginberri Billabong ICPMS results for fish (ppm, dry weight)

Table F1 ICPMS results for August 1985 Mudginberri collection of forktail catfish flesh

*eriss*_id	Species	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U	K	Fe	Cu	Zn	Al	Na	Cr	Co	Ni
MI5037	FT	1320	420	0.891	1.360	0.015	4.340	0.162	<0.002	17700	78.9	2.0	33.6	26.1	3060	11.4	0.108	0.277
MI5048	FT	1240	343	0.640	0.950	0.006	2.540	0.063	0.008	18100	71.5	1.16	28.9	42.3	2210	8.6	0.097	0.309

FT = Forktail catfish

Table F2 ICPMS results for December 1985 Mudginberri collection of fish flesh

*Eriss*_id	Species	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
MI5047	BB	1300	11400	23.9	29.9	0.006	10.7	0.144	0.033	>	59.0	4.22	38.5	23.9	11900	2880	15000	0.122	1.41	<	<
MI5049	FT	1170	470	<	0.437	<	0.280	0.045	<	>	28.4	0.927	19.2	16.1	11400	1890	8890	0.176	0.881	<	<
MI5052/2	FT	1170	489	<	0.992	0.019	1.65	0.313	<	>	63.7	1.37	34.9	4.57	14700	2620	10600	<	0.988	<	<
MI5052/3	FT	1260	550	0.654	0.938	0.014	1.63	0.109	<	>	67.0	1.92	49.1	7.11	13500	2550	12600	0.155	0.703	<	<
MI5053	BR	1280	918	0.676	1.00	0.011	1.82	0.175	<	>	50.2	2.00	15.7	6.58	13900	1850	9840	<	1.11	<	<

BB = Bony Bream, BR = Barramundi, GT = Forktail Catfish, <: Less than detection limit; nc: not certified; (): information value only

1. ">" indicates over range reading (> approx. 7000ppm K)
2. Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved
3. The digestion performance could not be verified for Sb, Th and U as reference materials certified for these elements were inadequate or unavailable.

Table F3 ICPMS results for February 1988 Mudginberri collection of fish flesh

*eriss*_id	Species	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
MI8002	BR	1350	505	0.528	0.560	0.009	0.129	0.111	<	>	16.6	0.714	12.3	5.13	10800	1390	11000	<	1.16	<	<
MI8003	FT	1200	432	0.868	1.09	0.020	1.11	0.180	<	>	55.0	1.63	44.0	11.3	13400	2290	9920	<	0.989	<	0.053
MI8004	SA	1170	1030	0.716	1.85	<	0.289	0.052	<	>	31.4	0.791	26.6	2.46	11600	3860	10000	<	1.77	<	<
MI8005	BB	1400	3260	5.78	6.40	0.019	1.73	0.181	<	>	20.3	1.73	21.4	6.42	11600	2250	12900	<	0.968	<	<

BB = Bony Bream, SA = Saratoga, BR = Barramundi, GT = Forktail Catfish, <: Less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for these elements were inadequate or unavailable.

Table F4 ICPMS results for March 1988 Mudginberri collection of fish flesh

*eriss*_id	Species	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
MI8007	BB	1400	4430	8.74	7.46	0.007	2.20	0.134	<	>	88.0	2.29	18.8	17.9	10500	2920	13800	0.115	1.07	<	<
MI8008	SA	1310	1040	1.28	2.19	0.006	0.315	0.078	<	>	66.7	1.11	16.6	4.64	12000	2510	9370	0.120	1.98	<	<
MI8009	BR	1120	461	0.549	0.481	0.010	0.177	0.136	<	>	38.1	0.764	13.8	7.53	10400	1600	8490	<	0.968	<	<

BB = Bony Bream, SA = Saratoga, BR = Barramundi, < less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for these elements were inadequate or unavailable.

Table F5 ICPMS results for February 1995 Mudginberri collection of fish flesh

*eriss*_id	Species	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
MI9501	FT	1090	494	0.602	0.925	0.024	1.01	0.072	<	>	44.0	3.90	45.1	8.30	11400	2190	7380	<	0.748	0.428	<

FT = Forktail Catfish, <: Less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for these elements were inadequate or unavailable.

Table F6 ICPMS results for fish flesh Mudginberri Billabong, May 2000

*eriss*_id	Species	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U	K	Fe	Cu	Zn	Al	Na	Cr	Co	Ni
MI0002	FT	1195*	336*	6.49*	1.315	0.0365*	1.42*	0.017*	0.0035*	18600*	41*	1.21*	55.3*	11.35*	3325*		0.087	
MI0003	FT	1200	294	1.17	1.240	0.091	2.35	0.23	<0.002	17100	38	2.47	64.5	16.7	2820	<1	0.156	0.163
MI0004	FT	1130	310	0.416	1.170	0.01	0.737	0.098	0.01	17700	27.5	1.12	99.1	15.6	2550	<1	0.119	0.222
MI0005	FT	1240	417	0.935	2.8	0.288	1.7	0.41	0.270	17600	52.7	1.93	87.7	21.6	4900	<1	0.422	0.352
MI0006	FT	1290	434	0.422	1.56	0.025	1.91	0.18	0.003	18000	35.5	1.24	54.8	10.9	2370	<1	0.06	0.116
MI0007	SA	1520	755	0.682	1.84	<0.005	0.301	0.020	<0.002	17600	10.2	0.751	23.4	6.14	2430	<1	0.014	<0.04
MI0008	ET	972	289	0.442	0.851	0.076	0.139	0.488	<0.002	12500	12.2	0.610	19.6	4.18	1400	<1	0.069	0.060
MI0009	ET	884	1670	1.85	4.93	0.026	0.416	0.185	0.009	10100	10.9	0.920	27	4.36	1870	<1	0.04	0.124
MI0011	ET	851	244	0.464	0.592	0.028	0.101	1.96	<0.002	8720	16	0.756	24	3.65	1480	<1	0.047	0.139
MI0012	BB	1510	11200	31.1	27.9	0.011	4.32	1.59	0.028	18800	64.4	0.981	27.3	26.4	2980	<1	0.111	0.483

(F) Filtrate, (P) Particulate, FT = Forktail catfish, ET = Eel Tail catfish, SA = Saratoga, BB = Bony Bream, * = mean value

Table F7 ICPMS results for fish flesh, liver and kidney Mudginberri Billabong May 2000 (leGras 2000)

***eriss*_id**	**Sample**	**Part**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**Fe**	**Cu**	**Zn**	**Al**	**As**	**Ag**	**Au**	**Bi**	**Co**	**Cr**	**Ni**
MI0010	ET 6	Flesh	1024	687	0.6	1.2	<0.5	0.26	0.2	<0.05	33	1	29	14	<0.5	<0.1	<0.05	<0.5	0.07	5	0.5
MI0010	ET 6	Liver	734	1316	14.6	9.5	0.16	2.48	4.9	<0.05	38557	15.9	168	159	<0.5	0.2	0.11	<0.5	0.73	16	0.9
MI0010	ET 6	Kidney	461	3895	2.7	3.1	0.11	0.31	0.3	<0.05	742	41.3	110	49	<0.5	<0.1	<0.05	<0.5	0.62	5	0.5
N/A	ET 9	Flesh	900	1129	0.9	1.9	<0.5	0.21	0.1	<0.05	77	1.1	35	20	<0.5	<0.1	<0.05	<0.5	0.1	5	0.3
N/A	ET 9	Liver	1032	2675	3.9	4.2	0.36	0.82	0.5	0.09	6730	10.1	148	17	<0.5	<0.1	<0.05	<0.5	1.49	6	0.7
N/A	ET 9	Kidney	499	4382	5.4	2.8	0.12	0.22	0.1	<0.05	1160	28.8	106	20	<0.5	<0.1	<0.05	<0.5	0.48	5	0.5
N/A	FT 10	Kidney	511	1287	2.7	12	<0.5	3.07	0.2	<0.05	1016	7.8	6783	10	<0.5	<0.1	<0.05	<0.5	1.64	6	1.2
N/A	FT 1	Kidney	772	1403	2	9	<0.5	2.25	0.3	<0.05	1159	4.8	9466	14	<0.5	<0.1	<0.05	<0.5	2.32	5	0.4
N/A	FT 10	Flesh	765	627	6.4	3.8	20.87	0.89	0.5	<0.05	1003	25.3	109	34	15.2	0.6	<0.05	<0.5	0.2	5	0.4
N/A	FT 1	Flesh	882	609	0.6	2	<0.5	4.94	1	<0.05	39	1.1	95	<10	<0.5	<0.1	<0.05	<0.5	0.18	5	0.3
N/A	FT 10	Liver	448	2947	4.4	7.5	0.07	2.08	0.3	<0.05	1968	49.5	2332	18	<0.5	<0.1	<0.05	<0.5	0.83	10	1.8
N/A	FT 1	Liver	611	1677	5.2	7.3	0.06	2.52	0.2	<0.05	5110	64.8	7471	18	<0.5	<0.1	<0.05	<0.5	0.96	4	0.3

FT = Forktail catfish, ET = Eel Tail catfish

Table F8 ICPMS results for fish flesh, gut, liver and kidney Mudginberri Billabong September 2003

*eriss*_id	Species	Part	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
MI03112	ET	Flesh	686	384	<	0.701	0.010	<	0.013	<	>	<	0.648	26.8	0.759	11000	2880	8180	<	1.97	<	<
MI03113	ET	Kidney	703	717	6.37	2.06	0.313	0.259	0.284	0.030	>	1880	146	176	19.2	9600	3250	12300	<	6.97	<	<
MI03114	ET	Liver	757	852	2.82	2.34	1.33	0.829	0.874	0.067	>	9440	4.98	73.2	21.1	9400	5730	12900	<	8.69	<	<
MI03115	ET	Guts	1125	1665	5.6943	5.36	0.031	1.95	0.112	0.033	>	455	7.26	131	92	8505	4340	12150	<	3.69	<	0.058
MI03116	FT	Flesh	974	5460	1.22	18.6	0.102	38.5	0.052	<	>	43.2	1.12	121	1.71	12400	3180	9680	<	0.910	<	<
MI03117	FT	Kidney	569	798	3.94	3.61	0.089	3.23	0.236	0.014	>	9180	100	2410	46.0	10500	7800	9520	<	9.47	<	<
MI03118	FT	Liver	471	805	1.23	4.17	0.054	5.32	0.166	0.028	>	1640	8.09	9830	4.66	7410	4520	10300	<	8.45	<	<
MI03119	FT	Guts	147	713	3.98	3.51	0.006	3.47	0.036	<	3040	194	1.38	438	114	2410	1570	1520	<	0.685	<	0.052
MI03120	SA	Flesh	1330	54300	7.74	213	0.020	26.9	0.071	<	>	<	0.760	55.0	3.92	8280	3460	27200	<	0.824	<	<
MI03121	SA	Kidney	782	1150	2.01	6.32	0.674	28.1	0.076	0.010	>	872	4.36	121	172	13200	5280	10500	<	7.98	<	0.051
MI03122	SA	Liver	594	695	3.63	2.23	0.324	1.09	0.077	<	>	2850	24.2	73.1	9.58	8790	6800	10000	<	5.00	<	<
MI03123	SA	Guts	870	610	10.3	2.12	0.030	1.95	0.064	<	>	54.9	3.95	48.6	45.6	5200	1970	6110	<	1.11	<	<
MI03124	BB	Flesh	1140	30900	50.3	66.3	0.017	17.6	0.068	0.050	>	57.3	1.38	52.7	19.7	7390	2380	18800	<	0.971	<	<
MI03125	BB	Liver	811	2400	6.80	4.06	4.17	2.59	0.214	0.204	>	6280	72.1	90.1	131	9480	5110	13300	0.161	5.22	<	0.069
MI03126	BB	Kidney	479	<	18.4	0.449	0.036	2.35	0.166	0.046	>	875	3.64	87.2	342	8790	4680	4690	0.137	1.59	<	0.131
MI03127	BB	Guts	207	372	10.3	0.876	0.064	1.87	0.184	0.046	3660	555	6.96	43.0	291	2290	2240	3120	0.305	0.746	<	0.111
MI03128	TA	Flesh	815	22500	12.0	72.53	<	6.02	0.096	<	>	<	0.636	23.9	43.1	8040	1610	13000	<	0.649	<	<
MI03129	TA	Liver	358	1230	2.64	3.11	0.083	2.16	0.106	<	>	5710	48.6	105	27.5	7670	4460	6340	<	2.66	<	<
MI03130	TA	Guts	250	1850	4.34	5.64	0.026	2.21	0.128	<	>	160	3.02	37.7	34.5	4400	3260	3890	<	1.02	<	<

ETC = Eel Tail Catfish, FTC = Fork Tail Catfish, SA = Saratoga, BB = Bony Bream, TP = Tarpon

<: Less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for A21these elements were inadequate or unavailable.

Appendix G Alpha Spectrometry results for Mudginberri Billabong fish

Table G1 ^{226}Ra in Mudginberri fish flesh May 2000 (mBq/kg wet weight)

***eriss*_ID**	**Sample**	**^{226}Ra**
MI0002	FTC 2	64 ± 11.8
MI0003	FTC 3	307 ± 41
MI0004	FTC 4	82 ± 14
MI0005	FTC 5	156 ± 47
MI0006	FTC 6	139 ± 24
MI0007	Saratoga	24 ± 9
MI0008	ETC 2	<19
MI0011	ETC 7	< 53
MI0012	Bony Bream	156 ± 35

FTC = Forktail catfish, ETC = Eel Tail catfish

Table G2 ^{226}Ra and ^{210}Po results from Mudginberri forktail catfish flesh October 2002 (Bq/kg dry weight)

***eriss*_ID**	**^{226}Ra**	**^{210}Po**
MI02002	175 ± 42.	1.16 ± 0.06
MI02003	<247	1.04 ± 0.05
MI02004	<72	1.40 ± 0.07
MI02005	77 ± 33	1.20 ± 0.08
MI02006	273 ± 41	1.11 ± 0.06
MI02007	173 ± 45	0.74 ± 0.05
MI02008	<126	1.59 ± 0.13
MI02009	159 ± 38	0.76 ± 0.06
MI02010	188 ± 57	2.91 ± 0.13
MI02011	115 ± 41	0.82 ± 0.05
MI02012	<295	1.18 ± 0.07
MI02013	<253	1.63 ± 0.15
MI02014	<158	1.34 ± 0.13
MI02015	<230	0.73 ± 0.08
MI02016	<183	
MI02017	316 ± 93	0.98 ± 0.07
MI02018	465 ± 86	1.85± 0.15

Appendix H Physical data for fish collections at Sandy Billabong

Table H1 Physical data for October 2002 Sandy Billabong forktail catfish collection

*eriss*_id	whole fish length (mm)	Whole fish wet wt (g)	Wet wt flesh (g)	Dry wt (g)	Dry: Wet
SBB02002	444	919	128.3	24.75	0.193
SBB02003	403	791	88.34	17.69	0.200
SBB02004	370	625	96.46	20.85	0.216
SBB02005	325	377	60.15	11.46	0.191
SBB02006	332	390	57.43	11.92	0.208
SBB02007	405	729	23.63	4.33	0.183
SBB02008	291	248	103.52	21.11	0.204
SBB02009	459	655	94.13	17.43	0.185
SBB02010	325	351	52.12	9.82	0.188
SBB02011	295	268	34.7	6.65	0.192
SBB02012	339	406	68.94	14.67	0.213
SBB02013	315	358	55.21	11.89	0.215
SBB02014	293	202	29.01	5.47	0.189
SBB02015	312	268	30.91	6.25	0.202
SBB02016	330	315	49.42	9.52	0.193

Table H2 Physical data for September 2003 Sandy Billabong fish collection

*eriss*_id	Species	Tissue	Dry (g)	Wet	Dry:Wet
SBB03103	BC	Flesh	55.83	296.59	0.18824
SBB03104	BC	Liver	3.44	14.26	0.241234
SBB03105	BC	Kidney	4.33	23.39	0.185122
SBB03106	BC	Guts	41.39	120.24	0.344228
SBB03107	TC	Flesh	119.19	504.26	0.236366
SBB03108	TC	Liver	1.93	7.07	0.272984
SBB03109	TC	Kidney	3.66	21.69	0.168741
SBB03110	TC	Guts	9.72	33	0.294545
SBB03111	SC	Flesh	158.55	734.31	0.215917
SBB03112	SC	Liver	4.71	19.78	0.238119
SBB03113	SC	Kidney	10.17	51.32	0.198168
SBB03114	SC	Guts	48.3	132	0.365909
SBB03115	BB	Flesh	86.17	346.57	0.248637
SBB03116	BB	Liver	5.12	23.91	0.214136
SBB03117	BB	Kidney	0.1858	0.8836	0.210276
SBB03118	BB	Guts	18.52	31.66	0.584965
SBB03119	SA	Flesh	145.49	528.58	0.275247
SBB03120	SA	Liver	1.8955	8.4276	0.224916
SBB03121	SA	Kidney	0.9672	4.4719	0.216284
SBB03122	SA	Guts	17.6	58.1	0.302926
SBB03123	BLC	Flesh	84.08	315.59	0.266422
SBB03124	BLC	Liver	0.8449	4.1456	0.203806
SBB03125	BLC	Kidney	1.41	8.62	0.163573
SBB03126	BLC	Guts	1.6	8.97	0.178372
SBB03127	TP	Flesh	67.62	217.72	0.310582
SBB03128	TP	Guts	11.7616	19.9304	0.590134
SBB03129	TP	Kidney	2.204	6.3507	0.347048

BC = Blue catfish, TC = Toothless Catfish, SC = Salmon Catfish, BB = Bony Bream,
SA = Saratoga, BLC = Black Catfish, TP = Tarpon

Appendix I ICPMS results for Sandy Billabong water

Table I1 ICPMS results for Sandy Billabong water (filtered), October 2002 (ppb)

***eriss*_id**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**S**	**Th**
SB02017	1230	891	2.100	8.69	1.920	3.42	1.650	0.023	308.0	55.6	<	40.800	<	<

Table I2 ICPMS results for Sandy Billabong water (filtered), 2003 (ppb)

***eriss*_id**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**Na**	**As**	**Se**	**Th**	**V**	**SL**
SBB03130	1270	845	1.27	4.94	<	2.43	0.094	0.014	302	58.1	0.602	57.7	2110	0.177	<	<	<	<
SBB03131	1230	786	1.10	5.06	<	2.36	0.254	0.007	354	29.1	0.527	20.8	2250	0.165	0.253	<	<	<

Appendix J Alpha spectrometry results for Sandy Billabong water

Table J1 ^{226}Ra and ^{210}Po results from Sandy Billabong water October 2002 (mBq/L for water and mBq/kg dry weight of residue)

***Eriss*_id**	**^{226}Ra**	**^{210}Po**
SBB02001 F		0.001 ± 0
SBB02001 R		
SBB02017 R	0.21 ± 0.09	
SBB02017 F	<1.0	0 ± 0

F – filtrate R - residue

Appendix K ICPMS results for Sandy Billabong sediment

Table K1 ICPMS results for Sandy Billabong sediment, October 2002 (ppm, dry weight)

***eriss*_id**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba**	**Pb**	**U**	**K**	**Fe**	**Cu**	**Zn**	**S**	**Th**
SBB02018	64.5	<	22.2	18.2	0.031	4.87	1.11	0.292	245	4420	1.42	1.47	25.4	1.45

Table K2 ICPMS results for Sandy Billabong sediment, October 2003 (ppm, dry weight)

***eriss*_id**	**Mg**	**Ca**	**Mn**	**Sr**	**Cd**	**Ba** [1]	**Pb**	**U** [1]	**K**	**Fe**	**Cu**	**Zn**	**Al**	**S**	**Na**	**P**	**As**	**Se**	**Th** [1]
SBB03132	8230	39.5	479	66.7	0.863	45.5	44.3	0.939	2320	18200	6.10	67.0	28200	25.6	157	368	<	4.90	4.30

Appendix L ^{226}Ra and ^{228}Ra/^{226}Ra ratios gamma spectrometry results for Sandy Billabong sediments (Bq/kg dry weight)

Table L1 ^{26}Ra and ^{228}Ra/^{226}Ra ratios gamma spectrometry results for Sandy Billabong sediments

Collection	^{226}Ra	^{228}Ra	^{228}Ra/^{226}Ra ratio	^{228}Th	^{210}Pb	^{40}K
October 2002	7.3 ± 1.0	6.7 ± 2.1	0.9 ± 0.6	9.2 ± 1.1	-	-
October 2003	6.3 ± 1.0	12.1 ± 2.6	1.9 ± 1.0	6.1 ± 1.4	15.6 ± 6	19 ± 10

Appendix M Sandy Billabong ICPMS results for fish flesh

Table M1 ICPMS results for fish tissues Sandy Billabong September 2003 (ppm dry weight)

*eriss*_id	Species	Tissue	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
SBB03103	BC	Flesh	804	8510	1.73	43.6	<	59.6	0.036	<	>	50.8	0.973	236	1.21	11500	3680	8650	<	1.94	<	<
SBB03104	BC	Liver	483	1150	1.79	9.30	0.284	19.3	0.451	0.006	>	2630	5.92	11600	13.9	7030	4150	10200	<	13.1	<	<
SBB03106	BC	Guts	482	6470	9.84	31.6	0.036	19.2	0.116	<	5480	439	11.7	2740	71.1	5560	4200	6360	<	2.89	<	0.054
SBB03107	TC	Flesh	874	1210	1.56	3.86	0.020	0.325	0.029	<	>	57.7	0.854	25.7	0.521	9320	2190	6550	<	2.91	<	<
SBB03108	TC	Liver	541	439	1.89	2.49	4.86	36.4	0.371	0.065	>	1100	2.94	49.5	11.7	6830	4150	8250	<	5.51	<	0.061
SBB03109	TC	Kidney	664	788	6.94	3.52	1.39	2.45	1.74	0.035	>	6290	48.8	105	184	9100	8940	10300	<	6.25	<	0.067
SBB03110	TC	Guts	1240	2030	8.40	9.74	0.079	1.36	0.091	0.024	>	633	6.30	123	95.8	8090	2660	13200	<	4.40	<	0.063
SBB03111	SC	Flesh	770	578	0.551	2.66	0.018	23.9	0.046	<	>	58.2	0.712	122	0.515	12600	3530	6000	<	1.17	<	<
SBB03112	SC	Liver	443	636	1.37	5.47	0.074	14.0	0.159	<	>	1090	4.28	9760	6.10	6960	4210	10100	<	11.4	<	0.059
SBB03113	SC	Kidney	541	422	4.06	3.68	0.201	3.76	0.132	<	>	3470	76.9	2360	58.3	9540	6950	9290	<	13.2	<	<
SBB03114	SC	Guts	346	6730	3.91	42.5	0.034	6.82	0.071	<	5140	305	1.82	2050	6.94	5380	3760	4170	<	1.84	<	<
SBB03115	BB	Flesh	1080	37900	56.1	89.4	0.032	18.8	0.063	0.034	>	50.3	1.67	50.9	15.9	8960	3280	21000	0.114	1.54	<	<
SBB03116	BB	Liver	688	827	18.5	1.78	0.124	2.35	0.099	0.017	>	1120	11.0	113	206	9240	5540	6430	0.270	2.46	<	0.095
SBB03117	BB	Kidney	1040	623	6.50	1.47	5.62	2.44	0.210	0.281	>	8870	86.2	72.6	132	9990	4800	14000	0.243	7.90	<	0.094
SBB03118	BB	Guts	663	976	98.9	5.81	0.057	28.5	1.00	0.163	>	5990	6.53	52.9	2150	4330	3390	4890	0.445	0.935	<	0.663
SBB03119	SA	Flesh	1200	37700	2.80	124	0.022	14.5	0.070	<	>	<	0.742	52.9	1.85	10200	2520	19800	<	1.75	<	<
SBB03120	SA	Liver	547	518	2.18	1.41	0.246	0.534	0.056	<	>	3860	31.4	82.8	34.3	11500	6350	9210	<	10.6	<	<
SBB03121	SA	Kidney	849	998	1.94	7.27	0.534	13.3	0.224	<	14800	969	5.74	140	191	15800	6700	9370	<	12.7	<	<
SBB03122	SA	Guts	341	463	0.880	1.13	0.043	0.409	0.054	<	5760	150	2.16	58.4	6.95	8230	3700	3480	<	2.01	<	<
SBB03123	BLC	Flesh	1675	54800	10.89	374	0.0152	50.58	0.0795	<	>	114.47	5.49	118.44	51.48	6610.00	2585.00	278000	<	1.2666	<	0.054

*eriss*_id	Species	Tissue	Mg	Ca	Mn [2]	Sr	Cd	Ba	Pb	U [3]	K [1]	Fe [2]	Cu	Zn	Al [2]	S	Na	P	As	Se	Sb [3]	Th [3]
SBB03124	BLC	Liver	702	<	1.71	1.40	1.19	<	0.213	0.047	13900	1570	4.10	67.4	9.62	8990	5770	10000	<	5.96	<	0.054
SBB03125	BLC	Kidney	659	706	6.25	1.85	0.267	0.109	0.190	0.024	>	2670	98.0	164	73.5	10200	9020	11000	<	6.34	<	<
SBB03126	BLC	Guts	774	1150	5.19	3.01	0.068	2.09	0.465	0.023	>	3330	7.08	150	218	9370	8440	8970	<	3.09	<	0.094
SBB03127	TP	Flesh	736	9980	2.94	23.5	<	3.09	0.033	<	>	26.9	0.789	18.1	9.93	9560	2160	7940	<	1.39	<	<
SBB03129	TP	Kidney	302	355	1.18	1.03	0.183	1.52	0.135	<	5440	4120	23.5	62.7	12.2	6270	3340	4750	<	3.76	<	0.072

BC = Blue catfish, TC = Toothless Catfish, BB = Bony Bream, SA = Saratoga, BLC = Black Catfish, TP = Tarpon

Appendix N Alpha spectrometry results for Sandy Billabong fish flesh

Table N1 ^{226}Ra and ^{210}Po results from Sandy Billabong forktail catfish flesh October 2002 (mBq/kg dry weight)

***eriss*_id**	**^{226}Ra**	**^{210}Po**
SBB02002	137 ± 61	1.01 ± 0.08
SBB02003	<193	0.61 ± 0.07
SBB02004	<179	1.27 ± 0.16
SBB02005	155 ± 67	1.73 ± 0.20
SBB02006	<554	1.01 ± 0.17
SBB02007	246 ± 100	1.71 ± 0.26
SBB02008	<512	0.94 ± 0.22
SBB02009	<312	1.27 ± 0.27
SBB02010	<143	
SBB02011	<105	
SBB02012	128 ± 38	
SBB02013	185 ± 83	
SBB02014	312 ± 87	
SBB02015	202 ± 76	
SBB02016	<239	

Appendix O Physical data for Mudginberri Billabong mussels

Table O1 Physical data for Mudginberri mussel flesh May 2000

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI0014	0.5274	4.5221	0.11663	5
MI0015	0.4784	3.8724	0.12354	5
MI0016	0.4112	3.814	0.10781	5
MI0017	0.155	1.6197	0.09570	2
MI0018	0.2143	2.7623	0.07758	5
MI0019	0.2011	3.4015	0.05912	3
MI0020	0.2788	3.3817	0.08244	2
MI0021	0.3951	4.746	0.08325	5
MI0022	0.327	4.3977	0.07436	4
MI0023	0.1838	2.6923	0.06827	3
MI0024	0.2767	3.5488	0.07797	4
MI0025	0.4148	4.3636	0.09506	4
MI0026	0.5709	7.1462	0.07989	6
MI0027	0.506	7.0085	0.07220	6
MI0028	0.3498	5.0755	0.06892	4
MI0029	0.3622	5.1198	0.07074	5
MI0030	0.4694	5.8313	0.08050	5
MI0031	0.1551	1.9659	0.07890	4
MI0032	0.1435	1.7662	0.08125	1
MI0033	0.3302	3.2546	0.10146	4
MI0034	0.2591	2.9056	0.08917	4
MI0035	0.7839	6.8897	0.11378	5
MI0036	0.3009	2.8752	0.10465	3
MI0037	0.5958	5.7518	0.10358	4
MI0038	0.4508	4.9686	0.09073	5
MI0039	0.4804	4.5849	0.10478	5
MI0040	0.2063	2.2869	0.09021	5
MI0041	0.8519	7.9387	0.10731	7
MI0042	0.4579	5.0579	0.09053	7
MI0043	0.238	2.4944	0.09541	4
MI0044	0.4252	3.8132	0.11151	6
MI0045	0.2475	2.1779	0.11364	4
MI0046	0.6911	6.811	0.10147	9
MI0047	0.8394	6.9307	0.12111	10
MI0048	0.2005	1.9568	0.10246	4
MI0049	0.3367	3.3275	0.10119	4
MI0050	0.214	2.108	0.10152	2
MI0051	0.191	2.3592	0.08096	4
MI0052	0.2153	2.4334	0.08848	5

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI0053	0.357	3.7695	0.09471	5
MI0054	0.486	5.4061	0.08990	6
MI0055	0.2551	2.8527	0.08942	2
MI0056	0.1774	1.7037	0.10413	3
MI0057	0.6079	5.9386	0.10236	6
MI0058	0.3016	2.9665	0.10167	3
MI0059	0.5417	4.338	0.12487	9
MI0060	0.2447	2.2379	0.10934	6
MI0061	0.4977	4.8251	0.10315	6
MI0062	0.1814	2.0957	0.08656	2
MI0063	0.2797	2.4901	0.11232	3
MI0064	0.5706	5.0791	0.11234	4
MI0065	0.343	2.9621	0.11580	5
MI0066	0.2209	2.5585	0.08634	2
MI0067	0.241	2.5624	0.09405	2
MI0068	0.4888	3.6015	0.13572	8
MI0069	0.266	2.6712	0.09958	4
MI0070	0.2097	1.9074	0.10994	2
MI0071	0.4188	4.0519	0.10336	7

Table O2 Physical data for Mudginberri Mussel flesh October 2000

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI0074	0.6242	6.9174	0.090236	2
MI0075	1.2472	9.3984	0.132703	4
MI0076	1.3338	9.3051	0.143341	2
MI0077	1.8412	15.2982	0.120354	5
MI0078	1.0325	10.1248	0.101977	5
MI0079	2.7751	18.4334	0.150547	8
MI0080	1.6439	10.4772	0.156903	4
MI0081	1.1385	11.6746	0.097519	5*
MI0082	0.9992	7.8928	0.126596	2
MI0083	1.1871	13.3624	0.088839	2
MI0084	0.985	11.7256	0.084004	3
MI0085	1.7265	13.8843	0.124349	4
MI0086	0.9139	8.894	0.102755	2
MI0087	1.1774	11.8093	0.099701	2
MI0088	1.5407	10.4557	0.147355	4
MI0089	1.2648	10.1693	0.124374	2
MI0090	1.8773	13.1524	0.142734	6
MI0091	1.3085	11.3249	0.115542	2
MI0092	1.8204	16.5863	0.109753	5
MI0093	1.2728	13.0263	0.09771	6
MI0094	0.7244	8.3835	0.086408	
MI0095	1.7146	12.6882	0.135133	6
MI0096	1.4519	10.2572	0.141549	2
MI0097	1.545	10.7035	0.144345	5
MI0098	1.2249	10.2841	0.119106	2
MI0099	0.8729	8.7654	0.099585	2
MI00100	1.232	12.6994	0.097012	7*
MI00101	1.3322	9.6269	0.138383	5
MI00102	1.0275	9.3985	0.109326	4
MI00103	1.1601	11.5516	0.100428	6*
MI00104	1.1045	9.9453	0.111057	3*
MI00105	1.1598	10.6163	0.109247	3
MI00106	1.3311	11.6876	0.11389	4*
MI00107	1.6502	12.2069	0.135186	4*
MI00108	1.5806	12.0355	0.131328	3
MI00109	1.5478	11.7162	0.132108	2
MI00110	0.9165	9.6104	0.095365	2
MI00111	0.7122	7.5617	0.094185	3

Table O3 Physical data for Mudginberri mussel flesh September 2001

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI0113	4.2261	14.7215	0.28707	2
MI0114	1.2984	9.4732	0.13706	5
MI0115	0.8413	8.2487	0.10199	2
MI0116	0.979	10.9035	0.08979	9
MI0117	0.8526	8.5796	0.09938	2
MI0118	0.8168	6.6511	0.12281	2
MI0119	0.7974	6.8727	0.11602	2
MI0120	1.0176	8.3665	0.12163	1
MI0121	1.6014	12.076	0.13261	4
MI0122	0.6181	5.938	0.10409	2
MI0123	0.8341	8.4751	0.09842	6
MI0124	1.6724	11.0251	0.15169	7
MI0125	2.6152	18.4677	0.14161	4
MI0126	0.7391	6.6261	0.11154	2
MI0127	0.845	8.2228	0.10276	4
MI0128	0.9972	9.362	0.10652	2
MI0129	0.6547	5.9747	0.10958	1
MI0130	1.2179	10.2109	0.11927	5
MI0131	1.2063	8.3794	0.14396	2
MI0132	0.9821	7.975	0.12315	7
MI0133	1.049	9.0375	0.11607	3
MI0134	1.8078	12.0466	0.15007	2
MI0135	1.6622	11.4893	0.14467	3
MI0136	1.9745	12.2954	0.16059	5
MI0137	1.194	8.5567	0.13954	3
MI0138	0.9874	8.4878	0.11633	3
MI0139	1.1329	7.9801	0.14197	1
MI0140	1.1543	9.482	0.12174	7
MI0141	1.0351	9.832	0.10528	2
MI0142	0.9984	7.8101	0.12783	4
MI0143	0.8599	8.094	0.10624	4
MI0144	0.8831	7.082	0.1247	6
MI0145	0.9522	8.8714	0.10733	5
MI0146	0.8479	7.6902	0.11026	2
MI0147	0.9695	8.5172	0.11383	3
MI0148	1.0547	8.7444	0.12061	4
MI0149	0.73	6.3053	0.11578	2
MI0150	0.8391	7.6892	0.10913	4
MI0151	1.7371	11.1362	0.15599	3
MI0152	1.0638	9.0989	0.11692	5
MI0153	0.9902	9.0989	0.10883	4

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI0154	0.6368	6.7103	0.0949	3
MI0155	1.077	10.3467	0.10409	3
MI0156	0.9938	8.9405	0.11116	4
MI0157	0.7394	6.833	0.10821	3
MI0158	0.7548	6.2956	0.11989	1
MI0159	0.9788	8.5602	0.11434	4
MI0160	1.4334	10.4681	0.13693	3
MI0161	1.2897	11.2604	0.11453	1
MI0162	1.2466	9.6246	0.12952	3
MI0163	1.6787	12.6613	0.13259	3
MI0164	0.8694	7.6283	0.11397	3
MI0165	0.978	8.0198	0.12195	1
MI0166	1.2829	10.5244	0.1219	2
MI0167	1.15	10.195	0.1128	2
MI0168	0.4947	5.3409	0.09262	1
MI0169	0.6208	5.6538	0.1098	1
MI0170	0.8638	5.6254	0.15355	3
MI0171	0.6209	6.1376	0.10116	1
MI0172	0.8435	6.9482	0.1214	2
MI0173	0.7996	7.6342	0.10474	1
MI0174	1.2289	8.6476	0.14211	2
MI0175	1.1262	8.31	0.13552	1
MI0176	0.3341	6.184	0.05403	2
MI0177	0.5921	5.6494	0.10481	4
MI0178	0.7349	6.5516	0.11217	1
MI0179	0.304	4.843	0.06277	1
MI0180	0.901	7.7561	0.11617	3
MI0181	1.2346	11.6748	0.10575	5
MI0182	0.7216	7.2172	0.09998	2
MI0183	0.693	6.3336	0.10942	3
MI0184	0.7747	7.2008	0.10759	3
MI0185	0.9334	8.4972	0.10985	4
MI0186	1.1285	8.3407	0.1353	2
MI0187	0.7314	7.456	0.0981	1
MI0188	0.8205	7.2316	0.11346	1
MI0189	0.7019	8.0621	0.08706	2
MI0190	0.9279	7.4188	0.12507	5
MI0191	1.0869	8.4216	0.12906	7
MI0192	1.5558	10.6575	0.14598	1

Table O4 Physical data for Mudginberri mussel flesh October 2002

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age
MI02021	1.9239	9.8579	0.195163	8
MI02022	1.7012	11.0632	0.153771	7
MI02023	0.8111	4.8497	0.167247	3
MI02024	1.6173	9.4739	0.170711	5
MI02025	0.9922	7.8378	0.126592	4
MI02026	1.1341	9.5416	0.118858	8
MI02027	1.2899	8.883	0.14521	7
MI02028	0.8939	7.2574	0.123171	5
MI02029	1.1692	8.3039	0.140801	7
MI02030	1.1476	7.7947	0.147228	4
MI02031	0.7609	7.521	0.10117	5
MI02032	1.4872	11.3975	0.130485	4
MI02033	0.7734	5.9939	0.129031	4
MI02034	1.1526	9.6876	0.118977	9
MI02035	0.883	7.5118	0.117548	5
MI02036	0.9028	6.4353	0.140289	3
MI02037	0.8246	7.4419	0.110805	8
MI02038	1.3953	9.9253	0.14058	5
MI02039	1.2814	9.4118	0.136148	8
MI02040	1.3165	10.3117	0.127671	6
MI02041	1.2655	10.4449	0.12116	11
MI02042	0.9168	7.8232	0.11719	3
MI02043	1.7737	16.7806	0.105699	9
MI02044	1.0195	7.6206	0.133782	4
MI02045	0.9907	7.4886	0.132294	6
MI02046	1.0436	5.9052	0.176726	5
MI02047	0.8648	7.3525	0.11762	5
MI02048	0.9987	7.9643	0.125397	4
MI02049	0.9246	6.2571	0.147768	8
MI02050	1.065	6.5973	0.16143	7
MI02051	1.0358	9.4049	0.110134	7
MI02052	0.8163	4.9466	0.165022	3
MI02053	1.1628	6.5321	0.178013	3
MI02054	0.6129	4.0757	0.150379	2
MI02055	1.1697	7.1656	0.163238	5
MI02056	0.8827	6.0146	0.14676	2
MI02057	1.4889	7.843	0.189838	5
MI02058	1.1505	7.7921	0.14765	5
MI02059	0.925	5.219	0.177237	5
MI02060	0.7049	4.6706	0.150923	3
MI02061	0.7785	4.4854	0.173563	2

*eriss*_id	Dry Wt	Wet wt	Dry:wet	Age
MI02062	1.2632	7.4492	0.169575	7
MI02063	1.1362	5.9446	0.191131	4
MI02064	1.3179	7.8045	0.168864	7
MI02065	1.3632	7.2997	0.186747	5
MI02066	1.3013	6.9625	0.186901	4
MI02067	1.1773	6.6673	0.176578	5
MI02068	1.4766	8.2738	0.178467	4
MI02069	1.0959	7.0093	0.156349	4
MI02070	1.0603	6.2937	0.16847	4
MI02071	0.7107	4.3763	0.162397	3
MI02072	0.5106	4.0738	0.125338	4
MI02073	1.1839	7.2349	0.163637	6
MI02074	0.6524	4.0468	0.161214	3
MI02075	1.1208	5.9623	0.187981	5
MI02076	1.2979	7.349	0.176609	7
MI02077	1.1556	6.3914	0.180805	4
MI02078	1.2907	7.9819	0.161703	5
MI02079	0.8054	5.0499	0.159488	6
MI02080	0.9926	6.2448	0.158948	3
MI02081	1.0107	5.923	0.17064	6
MI02082	1.0097	5.8913	0.171388	3
MI02083	1.4939	7.91	0.188862	12
MI02084	1.2536	7.098	0.176613	3
MI02085	1.1524	7.4553	0.154575	7
MI02086	0.8804	6.3879	0.137823	5
MI02087	1.1054	6.1782	0.178919	3
MI02088	0.45	2.9754	0.15124	1
MI02089	0.9149	5.0843	0.179946	5
MI02090	1.1104	7.0224	0.158123	10
MI02091	1.0661	7.9126	0.134734	12
MI02092	1.0385	5.8074	0.178824	4
MI02093	1.1231	6.4012	0.175451	6
MI02094	1.3996	8.8611	0.157949	4
MI02095	0.7352	4.5082	0.163081	2
MI02096	1.0431	5.9365	0.17571	6
MI02097	0.86	6.072	0.141634	3
MI02098	1.3347	7.6663	0.1741	10
MI02099	1.0119	5.5869	0.18112	3
MI02100	0.8417	5.1566	0.163228	5
MI02101	0.5241	4.069	0.128803	2
MI02102	1.1083	6.2949	0.176063	8
MI02103	0.5043	3.8796	0.129988	2

*eriss*_id	Dry Wt	Wet wt	Dry:wet	Age
MI02104	1.2845	7.7512	0.165716	5
MI02105	1.1287	6.7197	0.167969	4
MI02106	0.9143	6.5142	0.140355	3
MI02107	0.7699	5.2183	0.147538	4
MI02108	0.6176	5.8351	0.105842	4
MI02109	1.0101	6.2098	0.162662	4
MI02110	1.6469	9.6748	0.170226	6
MI02111	1.5174	7.3646	0.20604	5
MI02112	0.8881	6.2097	0.143018	4
MI02113	1.0559	6.1181	0.172586	10
MI02114	0.4944	4.385	0.112748	2
MI02115	1.4169	10.5819	0.133898	10
MI02116	0.9164	5.9759	0.153349	3
MI02117	1.3797	7.2217	0.191049	4
MI02118	0.8955	6.9148	0.129505	4
MI02119	1.2802	12.0621	0.106134	8
MI02120	1.0518	8.3099	0.126572	4
MI02121	1.2354	10.8276	0.114097	4
MI02122	0.7415	6.1105	0.121348	2
MI02123	0.9151	6.5707	0.13927	3

Table O5 Physical data for Mudginberri mussel flesh October 2003

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
MI03001	0.7364	5.7076	0.129021	2
MI03002	0.355	2.6657	0.133173	2
MI03003	0.6979	6.92	0.100853	3
MI03004	0.6091	5.0716	0.1201	1
MI03005	0.2613	1.9995	0.130683	1
MI03006	0.474	3.5545	0.133352	2
MI03007	0.8745	5.0755	0.172298	3
MI03008	0.4958	3.8896	0.127468	2
MI03009	1.2892	8.3186	0.154978	5
MI03010	0.732	4.9583	0.147631	2
MI03011	0.2136	1.581	0.135104	1
MI03012	0.7256	4.9726	0.14592	2
MI03013	1.293	8.3984	0.153958	4
MI03014	0.6585	5.1509	0.127842	6
MI03015	1.0332	7.278	0.141962	14
MI03016	0.5747	3.9966	0.143797	2
MI03017	1.4381	10.5707	0.136046	6
MI03018	1.1321	7.1732	0.157824	4
MI03019	0.905	6.7451	0.134171	4
MI03020	0.9217	6.1145	0.15074	2
MI03021	0.8879	7.4555	0.119093	7
MI03022	0.9831	6.3092	0.15582	3
MI03023	0.8296	5.9198	0.14014	4
MI03024	0.7564	5.0511	0.14975	5
MI03025	0.5243	3.5061	0.149539	1
MI03026	0.9139	6.296	0.145156	2
MI03027	0.9432	5.5309	0.170533	3
MI03028	0.8316	5.0058	0.166127	3
MI03029	0.8675	5.9622	0.1455	7
MI03030	1.1045	7.1133	0.155273	5
MI03031	0.6692	4.3023	0.155545	3
MI03032	0.6688	4.3836	0.152569	2
MI03033	0.4688	3.4493	0.135912	2
MI03034	0.8207	5.4961	0.149324	4
MI03035	0.5712	5.1732	0.110415	5
MI03036	0.7858	5.1798	0.151705	4
MI03037	1.0327	6.4712	0.159584	4
MI03038	0.6508	4.3422	0.149878	2
MI03039	1.208	7.1768	0.16832	6

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
MI03040	1.1749	6.6431	0.17686	4
MI03041	0.9218	6.3922	0.144207	9
MI03042	0.8954	5.5426	0.161549	4
MI03043	0.7967	5.5561	0.143392	4
MI03044	0.6686	4.1616	0.160659	2
MI03045	1.1528	7.6389	0.150912	5
MI03046	0.8019	4.9153	0.163144	2
MI03047	0.918	6.3083	0.145523	4
MI03048	0.5937	10.0453	0.059102	7
MI03049	0.5935	4.1915	0.141596	4
MI03050	1.8993	10.9335	0.173714	8
MI03051	0.2749	1.8996	0.144715	1
MI03052	0.927	5.8662	0.158024	3
MI03053	0.8443	4.8098	0.175537	3
MI03054	1.1982	8.0722	0.148435	8
MI03055	1.2458	7.9642	0.156425	7
MI03056	1.1218	7.0065	0.160108	5
MI03057	1.1401	6.3275	0.180182	4
MI03058	0.939	5.5056	0.170554	5
MI03059	0.9076	5.0507	0.179698	4
MI03060	1.1581	7.4008	0.156483	2
MI03061	1.1487	6.2771	0.182999	5
MI03062	1.1766	7.3976	0.159052	6
MI03063	1.1996	7.5345	0.159214	6
MI03064	1.4035	7.2778	0.192847	5
MI03065	0.9626	6.0777	0.158382	2
MI03066	0.5954	4.287	0.138885	2
MI03067	0.9018	5.577	0.1617	3
MI03068	1.0603	6.9596	0.152351	11
MI03069	0.7394	5.2506	0.140822	2
MI03070	1.0549	7.6422	0.138036	6
MI03071	0.8321	6.1608	0.135064	16
MI03072	0.7971	4.8372	0.164785	3
MI03073	0.393	3.7412	0.105047	5
MI03074	0.9782	5.8815	0.166318	3
MI03075	1.3839	7.0448	0.196443	5
MI03076	0.5588	3.8372	0.145627	2
MI03077	0.2576	1.7963	0.143406	1
MI03078	1.6146	10.0366	0.160871	7
MI03079	1.03	6.1658	0.167051	4
MI03080	0.6517	4.3411	0.150123	2

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
MI03081	0.391	2.788	0.140244	1
MI03082	1.4722	7.7512	0.189932	7
MI03083	1.1841	7.1176	0.166362	6
MI03084	0.7865	5.706	0.137837	2
MI03085	1.0758	5.9184	0.181772	6
MI03086	1.2276	6.8598	0.178956	6
MI03087	0.5308	3.58	0.148268	2
MI03088	0.399	2.462	0.162063	1
MI03089	0.4956	3.0099	0.164657	1
MI03090	0.9128	7.0049	0.130309	5
MI03091	0.8102	4.9073	0.165101	2
MI03092	1.1733	7.9581	0.147435	10
MI03093	1.1495	6.721	0.171031	5
MI03094	1.0687	6.3646	0.167913	7
MI03095	0.1812	1.1113	0.163052	1
MI03096	1.0327	6.6123	0.156179	6
MI03097	0.1981	1.3698	0.14462	1
MI03098	0.1279	0.7085	0.180522	1
MI03099	0.2199	1.4932	0.147268	1
MI03100	0.1746	1.3765	0.126843	1
MI03101	0.1256	1.1691	0.107433	1
MI03102	0.1914	1.2932	0.148005	1
MI03103	0.2068	1.3699	0.15096	1
MI03104	0.2338	1.4757	0.158433	1
MI03105	0.1958	1.3217	0.148143	1
MI03106	0.2713	2.1474	0.126339	1
MI03107	0.7716	4.1301	0.186824	2
MI03108	1.0621	6.1602	0.172413	5
MI03109	1.0598	7.7299	0.137104	5
MI03110	1.1878	7.6138	0.156006	6
MI03111	0.7337	4.3519	0.168593	9

Appendix P ICPMS results for Mudginberri Billabong mussels (ppm dry weight)

Table P1 ICPMS Results for mussel flesh October 2000

Age	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U
2	387	4240	1190	98	0.307	568.0	0.94	0.067
3	653	7850	2130	179	0.579	1060.0	1.82	0.136
4	651	8670	2490	206	0.923	1180.0	3.55	0.116
5	303	5440	1410	143	0.334	883.0	2.23	0.061
6	714	14200	4150	317	1.090	1830.0	6.34	0.151
*8	479	2750	629.0	52	0.239	291	2.65	0.075

*single mussel only

Table P2 ICPMS results Mudginberri mussel flesh September 2001

Age	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U	K	Fe	Cu	Zn	Al	Cr	Co
1	657	10900	2060	140	0.62	791	1.34	0.25	1700	7300	6.84	232	52.6	0.45	0.65
2	647	11200	2110	158	0.61	1040	1.8	0.25	1530	10100	5.39	226	58.4	0.66	0.74
3	630	13200	2350	182	0.77	1130	2.59	0.17	1360	11700	5.7	216	62.9	0.77	0.81
4	786	19800	3340	269	1.08	1630	4.19	0.20	1520	16600	6.65	270	91.7	1.16	1.15
5	824	18100	3010	224	1.64	1450	4.25	0.18	1570	14900	6.27	247	90.6	1.17	1.02
6	850	23900	4160	330	2.05	2130	6.34	0.24	1580	19800	10.8	280	85.5	1.51	2.09
7	954	24500	3670	300	2.13	1960	5.64	0.18	1510	17300	8.3	275	56.1	0.91	1.16
9	888	30600	4320	370	2.88	2420	14.3	0.26	1520	22400	7.53	338	79.7	1.51	1.73

Table P3 ICPMS results for Mudginberri mussel flesh October 2002 mussel collection

Age	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U	K	Fe	Cu	Zn	Th	S
1#	909	11300	3450	238	0.530	1070	1.45	0.14	2440	20700	9.4	214	0.02	5070
2	676	7760	2180	142	0.215	622	0.84	0.13	1990	8890	5.9	211	0.03	4090
3	668	10100	2510	182	0.273	837	1.36	0.12	1700	13200	5.5	204	0.03	3740
4	744	13100	3710	266	0.426	1260	1.97	0.13	1760	18800	6.6	241	0.04	3950
5	859	15200	4040	306	0.377	1460	2.15	0.14	1840	19900	6.7	252	0.05	4090
6	795	16300	4940	353	0.435	1710	2.54	0.16	1630	24500	4.9	268	0.05	3980
7*	838*	16000*	4080*	343*	0.269*	1665*	2.33*	0.14*	1625*	25100*	5.9*	238*	0.05*	4095*
8	1030	22000	6130	478	0.507	2280	3.45	0.17	1660	31800	5.5	311	0.06	4240
8#	918	36500	12000	562	0.482	3210	6.21	0.29	399	65400	14.3	472	0.09	5370
9	935	18000	7210	464	1.450	2260	6.51	0.19	1590	37100	6.6	274	0.09	4490
10	1140	30600	10500	721	1.370	3560	8.53	0.27	1580	56700	4.8	417	0.10	4250
11#	962	21100	5620	508	0.312	2800	4.23	0.14	1410	48900	6.3	256	0.05	4150

* Mean value from sample duplicates

Single mussels

Table P4 ICPMS results for Mudginberri mussel flesh October 2003 mussel collection

Age	Mg	Ca	Mn[2]	Sr	Cd	Ba	Pb	U[3]	K[1]	Fe[2]	Cu	Zn	Al[2]	S	Na	P	As	Se	Sb[3]	Th[3]
1	708	11300	2200	145	0.329	824	0.877	0.125	1880	6980	6.81	189	13.4	4430	1330	13200	1.13	1.27	<	0.056
2	621	11600	2130	160	0.297	1090	1.21	0.112	1680	9660	6.72	199	15.2	4200	1130	13400	1.24	1.14	<	0.063
3	683	16100	2980	232	0.243	1670	1.55	0.136	1590	13500	7.39	195	23.0	4470	1060	16400	1.31	1.18	<	0.069
4	692	18000	3230	263	0.344	1860	1.79	0.141	1570	16200	7.28	208	22.4	4430	1140	17600	1.47	1.08	<	0.077
5	733	21600	3920	301	0.440	2200	2.28	0.162	1590	18000	7.21	221	35.5	4270	1260	19600	1.84	1.19	<	0.090
6	789	26200	5060	394	0.689	2880	3.29	0.155	1600	23900	7.25	252	45.3	4190	1250	24100	2.13	1.25	<	0.100
7	702	23200	4810	359	0.563	2630	2.90	0.162	1460	23400	6.15	233	41.4	4180	1150	22600	2.11	1.25	<	0.099
8	880	34500	7780	534	1.34	3750	5.96	0.166	1630	35500	6.22	328	49.9	4240	1530	30600	2.18	1.34	<	0.105

<: Less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for A21these elements were inadequate or unavailable.

Appendix Q ^{226}Ra and ^{210}Po alpha spectrometry analysis for single Mudginberri Billabong mussels (Bq/kg dry weight)

Table Q1 ^{226}Ra and ^{210}Po activity concentrations May 2000 mussel flesh

Age	^{210}Po	^{226}Ra
1		454 ± 27
2	672 ± 44	
8	895 ± 34	1230 ± 80

Table Q2 ^{210}Po October 2000 mussel flesh

Age	^{210}Po
7	511* ± 15*

*mean value

Appendix R Radionuclide concentration activities gamma spectrometry results for Mudginberri Billabong mussels (Bq/kg dry weight)

Table R1 Radionuclide activity concentrations mussel flesh May 2000

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
2	896 ± 10	316 ± 16	70 ± 5	475 ± 35
3	1338 ± 19	395 ± 30	205 ± 11	326 ± 61
5	1197.0 ± 5	365 ± 7	212 ± 3	601 ± 15
6	1744 ± 11	516 ± 15	353 ± 6	1055 ± 33
7	1873 ± 14	448 ± 20	366 ± 8	1050 ± 46

Table R2 Radionuclide activity concentrations mussel flesh October 2000.

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
2	289 ± 4	61 ± 12	31 ± 6	86 ± 26
3	404 ± 5	244 ± 12	143 ± 6	169 ± 24
4	441 ± 5	218 ± 8	108 ± 4	152 ± 16
5	601 ± 5	119 ± 7	20 ± 3	39 ± 13
6	724 ± 7	130 ± 9	48 ± 5	92 ± 18
8*	136 ± 6	165 ± 8	65 ± 4	126 ± 15

*single mussel only

Table R3 Radionuclide activity concentrations mussel flesh September 2001

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
1	225 ± 4	97 ± 6	12 ± 2	86 ± 12
2	414 ± 4	158 ± 6	51 ± 2	104 ± 11
3	469 ± 5	164 ± 7	61 ± 3	114 ± 14
4	660 ± 6	215 ± 9	115 ± 4	221 ± 17
5	661 ± 5	217 ± 7	108 ± 3	259 ± 15
7	980 ± 9	308 ± 13	183 ± 6	429 ± 27

Table R4 Radionuclide activity concentrations mussel flesh October 2002

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
2	379 ± 7	134 ± 13	30 ± 7	50 ± 30
3	530 ± 5	184 ± 9	63 ± 5	109 ± 22
4	724 ± 5	235 ± 8	106 ± 5	104 ± 19
5	759 ± 5	229 ± 8	124 ± 4	123 ± 19
6	1027 ± 7	315 ± 11	186 ± 6	139 ± 24
7	896 ± 7	261 ± 11	165 ± 6	106 ± 24
8	1312 ± 9	322 ± 14	257 ± 9	169 ± 31
10	1733 ± 11	398 ± 18	346 ± 12	443 ± 42
12	1921 ± 13	421 ± 22	372 ± 17	258 ± 54

Table R5 Radionuclide activity concentrations for mussel flesh October 2003

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
1	274 ± 5	99 ± 13	15 ± 6	27 ± 20
2	423 ± 4	138 ± 8	48 ± 4	63 ± 13
3	561 ± 7	192 ± 13	80 ± 6	83 ± 19
4	633 ± 5	217 ± 10	101 ± 6	102 ± 16
5	623 ± 5	278. ± 9	157 ± 7	153 ± 15
6	937 ± 6	292 ± 12	187 ± 7	148 ± 17
7	1002 ± 6	300 ±11	206 ± 7	157 ± 16
8	1299 ± 10	407 ± 20	259 ± 13	362 ± 32

Appendix S Physical data for Sandy Billabong mussels

Table S1 Physical data for Sandy Billabong mussel flesh October 2002

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age (est.)
SBB02019	0.5921	9.2937	0.06371	5
SBB02020	0.9458	5.605	0.168742	3
SBB02021	1.1059	9.0516	0.122177	7
SBB02022	0.802	8.8126	0.091006	5
SBB02023	0.6008	5.9254	0.101394	4
SBB02024	0.9249	9.5214	0.097139	8
SBB02025	0.9207	7.8949	0.11662	6
SBB02026	0.719	6.0002	0.119829	2
SBB02027	1.133	8.7239	0.129873	8
SBB02028	1.1993	11.1617	0.107448	8
SBB02029	1.0784	11.8474	0.091024	5
SBB02030	0.9545	7.9756	0.119678	9
SBB02031	0.7315	6.085	0.120214	4
SBB02032	0.4191	5.6698	0.073918	4
SBB02033	0.7978	8.1561	0.097816	5
SBB02034	0.5988	6.2519	0.095779	3
SBB02035	0.673	6.5354	0.102978	5
SBB02036	0.971	7.7946	0.124573	5
SBB02037	0.4212	4.5612	0.092344	3
SBB02038	0.6338	8.7739	0.072237	
SBB02039	1.181	10.5706	0.111725	9
SBB02040	0.7691	6.2845	0.12238	2
SBB02041	1.1263	11.4402	0.098451	5
SBB02042	0.4763	8.0635	0.059069	5
SBB02043	0.8369	8.4503	0.099038	6
SBB02044	1.0409	10.3026	0.101033	8
SBB02045	0.8815	11.0658	0.07966	7
SBB02046	0.8712	9.0638	0.096119	6
SBB02047	1.7494	13.2765	0.131767	6
SBB02048	1.1402	10.3936	0.109702	8
SBB02049	0.7701	9.3047	0.082765	5
SBB02050	1.2512	11.815	0.105899	7
SBB02051	0.867	7.7423	0.111982	8
SBB02052	0.6905	8.3582	0.082613	4
SBB02053	1.2026	11.4648	0.104895	12
SBB02054	1.0076	10.227	0.098524	7
SBB02055	0.8646	7.4087	0.116701	3
SBB02056	0.9604	11.5092	0.083446	5
SBB02057	0.6143	11.9035	0.051607	8

*eriss*_id	Dry Wt	Wet Wt	Dry:wet	Age (est.)
SBB02058	0.7773	6.2268	0.124831	4
SBB02059	0.8729	8.9102	0.097966	4
SBB02060	1.0553	8.9704	0.117642	7
SBB02061	0.5408	4.7824	0.113081	2
SBB02062	0.5481	7.8276	0.070021	10
SBB02063	1.0538	14.6532	0.071916	8
SBB02064	1.2682	10.5606	0.120088	9
SBB02065	0.5722	6.0145	0.095137	5
SBB02066	0.8932	8.2188	0.108678	7
SBB02067	0.9978	10.5459	0.094615	8
SBB02068	0.7474	9.7743	0.076466	5
SBB02069	0.5836	9.1376	0.063868	12
SBB02070	0.689	6.689	0.103005	5
SBB02071	0.4114	6.2845	0.065463	5
SBB02072	0.892	9.4956	0.093938	2
SBB02073	0.602	6.2784	0.095884	5
SBB02074	1.0885	13.3382	0.081608	11
SBB02075	1.2149	10.7288	0.113237	6
SBB02076	1.0109	9.242	0.109381	4
SBB02077	1.1434	9.478	0.120637	8
SBB02078	0.6912	8.285	0.083428	4
SBB02079	0.6789	7.1894	0.094431	5
SBB02080	0.721	7.2038	0.100086	8
SBB02081	0.763	5.5259	0.138077	4
SBB02082	0.4639	4.9878	0.093007	3
SBB02083	0.725	7.0392	0.102995	7
SBB02084	0.6291	6.1594	0.102137	6
SBB02085	1.1915	11.7158	0.1017	3
SBB02086	0.8429	8.3251	0.101248	6
SBB02087	0.6116	6.1505	0.099439	3
SBB02088	1.2533	16.5322	0.07581	10
SBB02089	0.7353	8.9989	0.08171	6
SBB02090	0.5001	5.5719	0.089754	3
SBB02091	0.6659	8.7808	0.075836	5
SBB02092	0.6142	6.2668	0.098009	2
SBB02093	1.1338	9.9414	0.114048	5
SBB02094	1.0122	10.2232	0.09901	7
SBB02095	1.0562	9.2797	0.113818	8
SBB02096	0.5881	6.3082	0.093228	5

Table S2 Physical data for Sandy Billabong mussel flesh October 2003

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
SBB03001	0.7668	6.3949	0.119908	7
SBB03002	0.9236	8.7738	0.105268	8
SBB03003	0.6283	6.7976	0.09243	9
SBB03004	0.5714	5.4179	0.105465	13
SBB03005	0.8844	7.9319	0.111499	6
SBB03006	0.7326	5.9436	0.123259	5
SBB03007	0.6919	6.6019	0.104803	8
SBB03008	0.6689	6.0031	0.111426	9
SBB03010	0.9241	6.5629	0.140807	8
SBB03011	0.569	5.0568	0.112522	8
SBB03012	0.902	6.5966	0.136737	6
SBB03013	0.6506	6.3962	0.101717	5
SBB03014	1.1037	7.1088	0.155258	6
SBB03015	0.8107	5.6715	0.142943	6
SBB03016	1.0832	7.1232	0.152066	8
SBB03017	0.8433	5.8284	0.144688	8
SBB03018	0.7644	5.2655	0.145171	5
SBB03019	0.8047	5.9348	0.13559	8
SBB03020	0.6055	5.0383	0.120179	8
SBB03021	0.9452	5.7835	0.16343	6
SBB03022	0.6089	4.062	0.149902	8
SBB03023	0.7414	5.3579	0.138375	7
SBB03024	0.6933	5.486	0.126376	7
SBB03025	0.7698	6.0503	0.127233	6
SBB03026	0.4706	3.4505	0.136386	6
SBB03027	0.8299	5.7296	0.144844	6
SBB03028	0.922	5.875	0.156936	7
SBB03029	0.8715	4.7167	0.184769	5
SBB03030	0.486	3.564	0.136364	5
SBB03031	0.8147	5.0552	0.161161	6
SBB03032	0.9424	6.3328	0.148813	7
SBB03033	0.716	5.8924	0.121512	10
SBB03034	1.0574	7.125	0.148407	6
SBB03035	0.8311	4.5091	0.184316	6
SBB03036	0.8445	5.4228	0.155731	4
SBB03037	0.7219	4.5497	0.15867	6
SBB03038	0.6269	4.3103	0.145442	8
SBB03039	0.5026	3.9563	0.127038	7
SBB03040	0.6506	4.0448	0.160848	5

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
SBB03041	0.7364	4.9019	0.150227	7
SBB03042	0.8534	5.8398	0.146135	6
SBB03043	0.6709	5.5389	0.121125	5
SBB03044	0.6446	4.7043	0.137024	6
SBB03045	0.5394	3.6651	0.147172	7
SBB03046	0.4918	4.1752	0.117791	6
SBB03047	0.3669	3.0543	0.120126	4
SBB03048	0.6131	4.0092	0.152923	5
SBB03049	0.701	4.4642	0.157027	6
SBB03050	0.5346	3.5302	0.151436	4
SBB03051	0.948	6.2114	0.152623	5
SBB03052	0.5483	3.823	0.143421	4
SBB03053	0.6068	3.4549	0.175635	3
SBB03054	0.3966	2.5632	0.154728	4
SBB03055	0.5722	3.9948	0.143236	6
SBB03056	0.8865	5.618	0.157796	8
SBB03057	0.6588	4.6165	0.142706	6
SBB03058	0.8054	7.3063	0.110234	5
SBB03059	0.9241	6.2646	0.147511	9
SBB03060	0.6479	4.9009	0.1322	6
SBB03061	0.8299	5.2093	0.159311	7
SBB03062	0.4578	3.3175	0.137995	3
SBB03063	1.074	7.8062	0.137583	8
SBB03064	0.8108	4.9613	0.163425	5
SBB03065	0.5184	3.9375	0.131657	6
SBB03066	1.101	6.7388	0.163382	6
SBB03067	0.6553	4.0071	0.163535	5
SBB03068	0.2939	2.2519	0.130512	2
SBB03069	0.3512	2.1114	0.166335	2
SBB03070	0.3825	2.6833	0.142548	3
SBB03071	0.2681	2.0406	0.131383	1
SBB03072	0.7034	4.1521	0.169408	5
SBB03073	0.5656	3.3427	0.169205	3
SBB03074	0.3577	2.8154	0.127051	3
SBB03075	0.2818	2.2876	0.123186	3
SBB03076	0.5685	3.8873	0.146245	6
SBB03077	0.5835	5.4615	0.106839	9
SBB03078	0.4135	3.2883	0.125749	2
SBB03079	0.3922	2.9056	0.134981	4
SBB03080	0.3893	2.7346	0.142361	1
SBB03081	0.3708	2.6865	0.138023	3

*eriss*_id	Dry Wt	Wet WT	Dry : Wet	Age
SBB03082	0.4012	2.547	0.157519	2
SBB03083	0.4053	2.8893	0.140276	4
SBB03084	0.4021	2.8018	0.143515	5
SBB03085	0.5099	3.1635	0.161182	4
SBB03086	0.371	2.8901	0.128369	4
SBB03087	0.2664	2.0721	0.128565	2
SBB03088	0.2213	1.843	0.120076	2
SBB03089	0.299	2.2107	0.135251	2
SBB03090	0.5344	3.2481	0.164527	6
SBB03091	0.2138	1.6191	0.132049	1
SBB03092	0.4085	2.3873	0.171114	3
SBB03093	0.1797	1.2557	0.143107	1
SBB03094	0.1467	1.2393	0.118373	1
SBB03095	0.6693	4.8591	0.137742	5
SBB03096	0.5471	3.1122	0.175792	6
SBB03097	0.6494	4.1822	0.155277	8
SBB03098	0.5937	3.622	0.163915	3
SBB03099	0.2065	1.5002	0.137648	1
SBB03100	0.3493	3.9434	0.088578	2
SBB03101	0.6994	3.7023	0.18891	3
SBB03102	0.105	0.9177	0.114416	1

Appendix T ICPMS results for Sandy Billabong mussels (ppm dry weight)

Table T1 ICPMS results for Sandy Billabong mussel flesh October 2002 mussel collection

Age	Mg	Ca	Mn	Sr	Cd	Ba	Pb	U	K	Fe	Cu	Zn	S	Th
2	807	10400	2260	204	0.39	794	0.31	0.082	2140	11400	8.2	265	4720	<DL
3	906	12900	2660	279	0.51	1100	0.53	0.100	2070	21600	6.5	312	4980	0.022
4	935	18400	3510	398	0.69	1630	0.73	0.094	1840	28000	7.2	321	4920	0.030
5	1010	19900	3240	379	0.67	1540	0.67	0.113	1900	26000	6.6	308	4970	0.036
5	920	18800	3260	367	0.66	1440	0.67	0.100	1820	24700	5.8	291	5110	0.036
6	977	20700	3700	444	0.78	1880	1.00	0.087	1710	33400	6.7	243	4340	0.033
7	1110	24200	4840	561	0.62	2450	1.26	0.098	1700	38600	5.4	320	4320	0.043
8	1170	26900	5640	644	0.57	2770	1.30	0.102	1660	47300	5.4	334	4050	0.050
8	1180	26100	5190	614	0.60	2660	1.24	0.128	1770	44700	5.7	326	4140	0.067
9	1050	21200	4270	487	0.46	2140	1.20	0.098	1600	37000	6.2	325	4380	0.045
10	1500	36500	7850	877	0.90	4100	2.30	0.119	1520	74900	5.1	382	4720	0.081
11	1520	36400	8370	848	0.36	3880	1.66	0.111	1640	62400	7.7	369	4510	0.066
12	1280	33700	7230	801	1.34	3950	1.95	0.100	1350	62300	3.8	352	4630	0.067

Table T2 ICPMS results for Sandy Billabong mussel flesh October 2003 mussel collection

Age	Mg	Ca	Mn[2]	Sr	Cd	Ba	Pb	U[3]	K[1]	Fe[2]	Cu	Zn	Al[2]	S	Na	P	As	Se	Sb[3]	Th[3]
2	1030	29600	4210	414	0.581	2460	0.861	0.126	2170	22900	6.95	328	24.6	5390	1760	25400	1.78	1.88	<	<
3	807	25000	3730	373	0.707	2090	0.721	0.090	1670	22000	6.17	268	25.1	4400	1320	21800	2.02	1.60	<	0.065
4	929	26300	4030	414	0.602	2480	0.787	0.102	1690	21900	5.93	294	29.9	4940	1430	22900	2.21	1.78	<	0.071
5	904	30200	4340	523	0.922	3370	1.20	0.102	1540	35200	6.63	283	37.1	4940	1480	26000	2.97	1.84	<	0.079
6	843	29150	4590	488	1	3065	1	0	1450	32200	6	253	31	4440	1350	25250	3	2	<	0
7	1050	44400	7740	767	1.31	4730	1.82	0.123	1390	51700	5.83	349	43.7	4950	1530	35100	3.19	1.86	<	0.101
8	1090	47850	7470	839	0.944	5320	1.77	0.129	1440	53000	6.21	317	56.7	5270	1620	37200	4.21	1.96	<	0.112
9	1130	46500	6640	731	2.01	4690	2.71	0.122	1350	43700	5.52	326	68.6	5270	1720	34000	4.76	2.29	<	0.111

<: Less than detection limit; nc: not certified; (): information value only

1 ">" indicates over range reading (> approx. 7000ppm K)

2 Less than quantitative recovery of Al, Fe and Mn in some certified reference materials (CRMs) indicate that mineral inclusions were not completely dissolved

3 The digestion performance could not be verified for Sb, Th and U as reference materials certified for A21these elements were inadequate or unavailable.

Appendix U Radionuclide concentration activities gamma spectrometry results for Sandy Billabong mussels (Bq/kg dry weight)

Table U1 Radionuclide activity concentrations for mussel flesh Sandy Billabong October 2002

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
2	136 ± 15	98 ± 19	21 ± 13	15 ± 58
3	207 ± 10	137 ± 15	45 ± 9	71 ± 40
4	292 ± 10	161 ± 14	79 ± 9	95 ± 38
5	367 ± 14	207 ± 17	118 ± 13	105 ± 52
6	389 ± 8	211 ± 13	121 ± 8	72 ± 31
7	478 ± 8	215 ± 11	179 ± 7	120 ± 28
8	520 ± 10	247 ± 14	196 ± 9	177 ± 35
9	483 ± 21	227 ± 29	205 ± 22	164 ± 83

Table U2 Radionuclide activity concentrations for mussel flesh Sandy Billabong October 2003

Age	^{226}Ra	^{228}Ra	^{228}Th	^{210}Pb
2	287 ± 10	190 ± 27	66 ± 14	79 ± 42
3	291 ± 6	177 ± 15	60 ± 8	96 ± 22
4	347 ± 6	196 ± 16	93 ± 8	84 ± 24
5	418 ± 4	247 ± 9	136 ± 5	120 ± 14
6	473 ± 5	243 ± 11	171 ± 6	145 ± 16
7	653 ± 6	314 ± 13	230 ± 7	169 ± 19
8	725 ± 6	347 ± 13	268 ± 8	201 ± 19
9	748 ± 9	356 ± 23	271 ± 12	352 ± 35