PROGRESS REPORT FOR AINGRA06186

PROJECT TITLE

History of natural environmental events in a pristine estuary: ostracod proxies and 210Pb chronology from Wingan Inlet, Victoria

INVESTIGATOR(S)

Chief Investigator: Dr Mark Warne
Institution and Department: Ecology and Environment, Deakin University
Other Investigators: N/A
Students: N/A
ANSTO Investigators: Jennifer Harrison & Atun Zawadzki

SCIENTIFIC OBJECTIVES

The principle objective of this project is to determine the chronology of natural environmental change events, as indicated by fossil ostracod proxies, in a pristine estuarine environment of S.E. Australia (Wingan Inlet). The purpose of this research is to establish a critical base-line "scientific control", against which environmental events in non-pristine estuaries of S.E. Australia can be compared and assessed with regard to anthropogenic impact(s).

PROGRESS REPORT and RESEARCH OUTCOMES

Field Work

Field work for this project was conducted in February, 2006 (1/2/06 – 18/2/06). Seven sediment cores ranging from 1.2 metres to 0.3 metres in length were collected from (1) mid to upper estuary settings, and (2) estuarine shoreline settings of Wingan Inlet, using Livingston and Russian (D-section) corers. Cores varied from 50 mm to 100 mm in diameter. Three of these cores were subsequently selected for detailed study (Wingan 2, Wingan 3 and Wingan 5). The Wingan 2 core was a 1 metre long (50 mm diameter) Livingston core taken in approximately 0.5 metres water depth at a very low tide. The core was from a mid estuary mudflat setting approximately 400 metres north of the Wingan Inlet jetty and approximately 40 metres from the western shore of the estuary. The Wingan 3 core was a 32 cm long (50 mm diameter) Livingston core from a position immediately adjacent to the Wingan 2 core. The reason for taking the Wingan 3 core was because of suspected collection-related sediment disturbance at the top of the Wingan 2 core. Both Wingan 2 and 3 cores were of mud with scattered shells and shell fragments. The Wingan 5 core was a 1.2 metre long (100 mm diameter) Livingston core taken in approximately 4 metres water depth at a very low tide. The core was taken from an upper estuary distributary channel setting approximately 1 km north of the Wingan Inlet jetty and approximately 70 metres from the western shore of the inlet. The Wingan 5 core ranged from a poorly sorted, shelly and muddy gravel near the base, to a poorly sorted sandy mud devoid of shelly material near the top of the core.

Laboratory Work

Laboratory work was conducted at Deakin University (Burwood Campus) during October – December, 2006. Lithological logs were created for selected cores (Wingan 2, 3 & 5 cores). Two suites of samples were taken from the cores. The first was dispatched (late in 2006) to Jennifer Harrison at ANSTO for 210Pb dating and the second reserved for micropalaeontological analyses of subfossil ostracod faunas. A total of 30 samples (0.5 – 1 cm slices) from the three cores were processed for 210Pb dating. A total of 13 samples (3 cm slices) from these three cores were processed as part of the micropalaeontological analyses. From the 13 micropalaeontological samples approximately 4,000 microscopic ostracod specimens were extracted. Analysis of the ostracod assemblages through each core then enabled the construction of a historical record of environmental change within this estuary.

Data

ANSTO reports on 210Pb dating of Wingan Cores 2, 3 & 5 (completed 2-4-2007) and ostracod fossil distribution tables are attached as appendices to this report. [Appendices 1, 2 & 3 - Pb210 dating reports; Appendix 4 – Ostracod distribution tables.]
Interpretation of Lead 210 Profiles

Thirty-one samples from Wingan Inlet sediment cores 2, 3 & 5 were sent to ANSTO for Pb210 dating. Of the thirty-one samples analysed, twenty-four samples generated results useful for dating core materials. Eleven representative ages from these twenty-four dated samples are indicated on the core diagrams below. [For reference to details of age determinations for all twenty-four dated samples - see appendices 1, 2 & 3.] Pb210 results for Core 2 indicate that only the upper 3.5 cms displayed Pb210 profiles consistent with undisturbed sedimentation over time, whilst below 9 cms depth (i.e. 9 - 100 cms) sediments appear to have undergone periods of mixing. An outcome of these Pb210 profiles is that ages for sediment accumulation can only be assigned for the upper 3.5 cms of core 2 [lowermost dated sample in core 2 at 3.0 ± 0.5 cm depth ~ 2002 / 2003]. Pb210 results for Core 3 indicate that sediments are probably not mixed through much of this relatively short core section. However, between 11 cms depth and 32 cms depth (base of core), only one sample at 30.0 ± 0.5 cms was submitted for Pb210 dating – this sample failing to yield a result on age because of very low unsupported Pb210 activity [lowermost dated sample in core 3 at 10.5 ± 0.5 cm depth ~ 1984]. Pb210 results for Core 5 (which extends down to 1.2 metres depth) generally indicate that sediments are not mixed except possibly for the top 13 cms of the core. [lowermost dated sample in core 5 at 58.5 ± 0.5 cm depth ~ 1923]. Increased prevalence of mixing in the top 13 cms of core 5 approximately correlates with a marked change in grain size, with finer material become more dominant in sediment samples above this depth interval.

Research Outcomes

Summary diagrams of the distribution of ostracod faunas through the Wingan 2, 3 & 5 core successions are presented below. All three cores, which come from the “middle to upper reaches” of the Wingan Inlet estuary, display a consistent pattern with respect to environmental change through time. Core segments from mid estuary (submerged mud bank) regions (Cores 2 & 3) dating back to periods prior to the early 1980’s, yield rich in situ fossil ostracod faunas indicative of well oxygenated mesohaline to polyhaline conditions adjacent to the estuary floor. This suggests relative good water circulation and subtidal water depths. Subsequent to the early 1980’s, these submerged mud bank regions, appear to have become periodically exposed “mudflat” regions, and generally contain low abundance / low diversity ostracod faunas (or no ostracod faunas).

In distributary channel regions (Core 5), ostracod faunas are rare because of the increased flow conditions, but there is evidence for overall decreased water velocity (flow) conditions from the sedimentary successions (up-sequence decrease in grain size) subsequent to the early 1980’s. This may be due to evulsion or decreased river discharge.

Given that Wingan Inlet is a strongly tidal estuary that is permanently open to the sea; it is possible that evidence for decreased water circulation subsequent to the early 1980’s within the middle to upper reaches of the estuary does relate to a long term trend of decreased river discharge and decreased sediment “flushing” from the estuary. This perhaps relates to decreased precipitation (rainfall) within the region over the last few decades up to 2006, and thus may relate to the effects of local climate variability or broader scale climate change.

The results and conclusions of this project are as yet preliminary, but have significant implications for the environmental impact of climate variability or change on the distribution and extent of estuarine benthic habitats.

Associated Projects

This project on the Wingan Inlet compliments parallel projects that have been, or are being undertaken on other estuaries along the coast of Victoria. These include similar 210Pb dating & fossil ostracod based studies on the Hopkins and Glenelg River estuaries of western Victoria (2006 Glenelg-Hopkins Catchment Management Authority project) and the Moyne River estuary of western Victoria (2007 AINSE Grant). Integration of results from all these projects will contribute to an understanding of broad scale environmental impacts on SE Australian estuaries.
Signature of Investigator preparing the report for
After signing this report please fax this page with your signature for our files

Date: 2-5-2007

PUBLICATIONS / REPORTS arising as a result of your work.
Not yet applicable, but planned.

PhD STUDENTS
N/A
Background

The naturally occurring radioactive uranium-238 (\(^{238}\text{U}\)) decays through a series of intermediates to radium-226 (\(^{226}\text{Ra}\)) then radon-222 (\(^{222}\text{Rn}\)) and ultimately to lead-210 (\(^{210}\text{Pb}\)). \(^{210}\text{Pb}\) in turn decays to bismuth-210 (\(^{210}\text{Bi}\)) then polonium-210 (\(^{210}\text{Po}\)) before finally decaying to stable \(^{206}\text{Pb}\). The \(^{210}\text{Pb}\) in sediments comprise both supported and unsupported components. The supported \(^{210}\text{Pb}\) is in equilibrium with all of the members of the decay chain that precede it. Unsupported \(^{210}\text{Pb}\) is derived from the portion of \(^{222}\text{Rn}\) (a noble gas) which diffuses through the soil interstitial pore space and is "lost" from its parent. The escaped \(^{222}\text{Rn}\) can diffuse into the atmosphere where it rapidly decays, with a half life of 3.8 days, to \(^{210}\text{Pb}\) which attaches to aerosol particles and settles out of the atmosphere as dry fallout or during rainfall events. This unsupported \(^{210}\text{Pb}\) derived from atmospheric fallout will enter the system as either direct input, falling directly into the lake or stream, or be delayed and enter the sediment as indirect input, falling elsewhere in the catchment and washed into the lake or river. In either event, once deposited and incorporated in the sediment, the activity of unsupported \(^{210}\text{Pb}\) will be solely a function of the amount present initially and its half life (\(t_{\frac{1}{2}} = 22.26\) years) (Goldberg, 1963 and Oldfield and Appleby, 1984).

The \(\text{in-situ}\) production of supported \(^{210}\text{Pb}\) can be measured indirectly by measuring the activity of \(^{226}\text{Ra}\) using either alpha or gamma spectrometry. Unsupported \(^{210}\text{Pb}\) cannot be measured directly and so is inferred from the activity of total \(^{210}\text{Pb}\) minus the activity of supported \(^{210}\text{Pb}\). The activity of total \(^{210}\text{Pb}\) can be determined by either measuring \(^{210}\text{Pb}\) directly using gamma spectrometry or measuring its progeny, \(^{210}\text{Po}\) (using alpha spectrometry), with which it is assumed to be in secular equilibrium.

Two \(^{210}\text{Pb}\) dating models are commonly used for calculating sediment rates: the CRS (constant rate of \(^{210}\text{Pb}\) supply) and the CIC (constant initial \(^{210}\text{Pb}\) concentration) models. The basic assumption of the CRS model is that the rate of supply of fallout \(^{210}\text{Pb}\) to the core site is constant, reflecting the constant flux of \(^{210}\text{Pb}\) from the atmosphere. The CIC (constant initial \(^{210}\text{Pb}\) concentration) model assumes that sediments in the core all had the same initial unsupported \(^{210}\text{Pb}\) concentration at the time they were laid down on the bed of the lake, regardless of differences in the sedimentation rate (Walling, et al., 2002).

Changes in grain size can affect the adsorption of unsupported \(^{210}\text{Pb}\) to sediments. Studies have shown that there can be an increase in unsupported \(^{210}\text{Pb}\) activity with an increase in the specific surface area of sediments (He and Walling, 1996). Therefore, the grain size distribution of sediments used for \(^{210}\text{Pb}\) dating need to be investigated to ascertain if there are other factors influencing the unsupported \(^{210}\text{Pb}\) activity other than radioactive decay.

Methodology

Samples for \(^{210}\text{Pb}\) dating were chemically processed using the following ANSTO methods: ENV-I-044-031 Sedimentation rate determination; ENV-I-044-006 Bulk iron removal by ether extraction; ENV-I-044-023 Polonium analysis; and ENV-I-044-027 \(^{226}\text{Ra}\) analysis. Each dried sediment sample was spiked with \(^{209}\text{Po}\) and barium-133 (\(^{133}\text{Ba}\)) yield tracers. Each sediment sample was subsequently leached with hot concentrated acids to release polonium and radium. Polonium was autoplated onto silver disks after adding the reducing agent hydriodicammonium chloride. Radium was co-precipitated with \(\text{BaSO}_4\) on a membrane filter source. The activity of the sample sources were determined by spectrometry methods.
Samples for grain size analysis were processed using the following ANSTO method: ENV-I-007-001 Particle Size Analysis using Laser Diffraction. Each wet sample was dispersed in water and pumped through a measurement chamber in a Malvern Mastersizer S laser particle analyser. The Malvern Mastersizer S uses laser diffraction to determine the particle size distribution of solids with a diameter in the range 0.05 µm to 880 µm. Solid particles outside this range are undetected.

Spectrometry

Sample sources were counted according to the following ANSTO method: ENV-I-044-001 Alpha spectrometry. Both the silver disk (\(^{210}\)Po/\(^{209}\)Po source) and membrane filter (\(^{226}\)Ra/\(^{133}\)Ba source) were counted by alpha spectrometry. The membrane filter was also counted by gamma spectrometry to measure \(^{133}\)Ba tracer activity. Chemical yield recoveries of \(^{210}\)Po and \(^{226}\)Ra were calculated using the recoveries of \(^{209}\)Po and \(^{133}\)Ba tracers.

Results

Table 1 shows sample descriptions, depths, cumulative dry masses and activity results. Grain size results are shown in Table 2. Table 3 shows sample depths, bulk densities, CIC and CRS calculated ages and CRS mass accumulation rates.

Total \(^{210}\)Pb (\(^{210}\)Po) activities are plotted against cumulative dry mass (Fig 1) and supported \(^{210}\)Pb (\(^{226}\)Ra) activities are plotted against cumulative dry mass (Fig 2). The \(^{226}\)Ra and \(^{210}\)Po activities were used to calculate unsupported \(^{210}\)Pb which is shown plotted against cumulative dry mass in Figure 3.

Interpretation

The activity of total \(^{210}\)Pb decreases with depth in the top 3.5 cm of the core. The activity of total \(^{210}\)Pb below 9 cm is almost constant and does not show a decreasing trend (see Figure 1). The activity of supported \(^{210}\)Pb is relatively constant over the length of the core (see Figure 2), suggesting there has been little change in local sediment input. The unsupported \(^{210}\)Pb activity shows a similar trend to the total \(^{210}\)Pb activity (see Figure 3).

The mass accumulation rates for this core were determined using unsupported \(^{210}\)Pb data in the top 3.5 cm of the core only. The rest of the unsupported \(^{210}\)Pb data for this core are very low and do not show a decay trend with depth. For this reason sediment layers below 3.5 cm cannot be dated by the \(^{210}\)Pb dating method. More samples should be analysed between 3.5 and 9 cm to determine more reliable mass accumulation rates calculations.

A single CIC model mass accumulation rate was calculated using the unsupported \(^{210}\)Pb data at 0.25 and 3 cm (0.2 and 1.7 g/cm\(^2\)). The sediment ages were then calculated and shown in Table 3.

\[\text{CIC Model Mass Accumulation Rate for Wingan Inlet Core 2:} \]
\[
0.223 \text{g/cm}^2/\text{y (Correlation Coefficient} = 1\text{, two data points only)}
\]
\[
\text{(calculated using unsupported} \; ^{210}\text{Pb data between 0-3.5 cm core depth)}
\]

The CRS model mass accumulation rates and sediment ages are shown in Table 3.

Grain size distribution data is useful for normalising \(^{210}\)Pb data in cases where the sediment within a core consists of varying types of material (clay/mud/sand). The grain size data shown in Table 2 suggests there may be two different sediment types within the core, a finer sediment material at the top 50 cm in comparison to those below 50 cm.

The mass accumulation rates calculated for this core were not normalised with grain size data.

References


Table 1 - Wingan Inlet Core 2: Sample numbers, depths and cumulative masses, count date and total $^{210}$Pb, supported $^{210}$Pb and decay corrected unsupported $^{210}$Pb activities.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Cumulative Dry Mass (g/cm$^2$)</th>
<th>Count Date</th>
<th>Total Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Supported Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Unsupported $^{210}$Pb Corrected to reference date 15-Dec-06 (mBq/g) or (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J682</td>
<td>0.25 ± 0.25</td>
<td>0.2 ± 0.2</td>
<td>07-Feb-07</td>
<td>69.1 ± 1.6</td>
<td>5.6 ± 0.4</td>
<td>63.8 ± 1.7</td>
</tr>
<tr>
<td>J684</td>
<td>3.0 ± 0.5</td>
<td>1.7 ± 0.3</td>
<td>07-Feb-07</td>
<td>56.1 ± 1.5</td>
<td>5.3 ± 0.4</td>
<td>51.1 ± 1.6</td>
</tr>
<tr>
<td>J686</td>
<td>9.5 ± 0.5</td>
<td>5.6 ± 0.3</td>
<td>07-Feb-07</td>
<td>9.8 ± 0.5</td>
<td>5.3 ± 0.4</td>
<td>4.5 ± 0.6</td>
</tr>
<tr>
<td>J688</td>
<td>29.5 ± 0.5</td>
<td>18.3 ± 0.3</td>
<td>07-Feb-07</td>
<td>11.9 ± 0.5</td>
<td>6.4 ± 0.5</td>
<td>5.6 ± 0.7</td>
</tr>
<tr>
<td>J690</td>
<td>49.5 ± 0.5</td>
<td>31.2 ± 0.3</td>
<td>07-Feb-07</td>
<td>13.7 ± 0.4</td>
<td>9.6 ± 0.7</td>
<td>4.1 ± 0.8</td>
</tr>
<tr>
<td>J692</td>
<td>69.5 ± 0.5</td>
<td>43.2 ± 0.3</td>
<td>05-Feb-07</td>
<td>8.0 ± 0.2</td>
<td>5.5 ± 0.4</td>
<td>2.6 ± 0.5</td>
</tr>
<tr>
<td>J694</td>
<td>96.5 ± 0.5</td>
<td>56.9 ± 0.3</td>
<td>05-Feb-07</td>
<td>6.8 ± 0.2</td>
<td>5.8 ± 0.5</td>
<td>1.1 ± 0.5</td>
</tr>
</tbody>
</table>

Table 2 - Wingan Inlet Core 2: Sample numbers, depths and grain size results for < 2 µm and < 63 µm fractions.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Clay &lt; 2 µm Content (%)</th>
<th>Mud &lt; 63 µm Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J696</td>
<td>0.5 - 1.5</td>
<td>0.59</td>
<td>62.5</td>
</tr>
<tr>
<td>J697</td>
<td>2.5 - 3.5</td>
<td>0.53</td>
<td>61.4</td>
</tr>
<tr>
<td>J699</td>
<td>9 - 10</td>
<td>0.61</td>
<td>56.1</td>
</tr>
<tr>
<td>J701</td>
<td>29 - 30</td>
<td>0.50</td>
<td>50.5</td>
</tr>
<tr>
<td>J703</td>
<td>49 - 50</td>
<td>0.41</td>
<td>79.7</td>
</tr>
<tr>
<td>J705</td>
<td>69 - 70</td>
<td>0.52</td>
<td>36.7</td>
</tr>
<tr>
<td>J707</td>
<td>79 - 80</td>
<td>0.46</td>
<td>33.4</td>
</tr>
</tbody>
</table>
Table 3 - Wingan Inlet Core 2: Sample numbers, depths, dry bulk densities, calculated CIC and CRS ages and CRS mass accumulation rates.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Dry Bulk Density (g/cm³)</th>
<th>Combined Calculated CIC Ages (years)</th>
<th>Calculated CRS Ages (years)</th>
<th>Mass Accumulation Rates g/cm²/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>J682</td>
<td>0.25 ± 0.25</td>
<td>0.58</td>
<td>0.67 ± 0.67</td>
<td>0.38 ± 0.33</td>
<td>0.39 ± 0.35</td>
</tr>
<tr>
<td>J684</td>
<td>3.0 ± 0.5</td>
<td>0.58</td>
<td>7.82 ± 1.30</td>
<td>4.21 ± 0.99</td>
<td>0.41 ± 0.10</td>
</tr>
<tr>
<td>J686</td>
<td>9.5 ± 0.5</td>
<td>0.60</td>
<td>6.72 ± 1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J688</td>
<td>29.5 ± 0.5</td>
<td>0.67</td>
<td>1.82 ± 0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J690</td>
<td>49.5 ± 0.5</td>
<td>0.62</td>
<td>4.21 ± 0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J692</td>
<td>69.5 ± 0.5</td>
<td>0.58</td>
<td>7.42 ± 1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J694</td>
<td>96.5 ± 0.5</td>
<td>0.44</td>
<td>1.82 ± 0.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 – Wingan Inlet Core 2: Total $^{210}$Pb ($^{210}$Po) activity versus cumulative dry mass.

Figure 2 – Wingan Inlet Core 2: Supported $^{210}$Pb ($^{226}$Ra) activity versus cumulative dry mass.
Figure 3 – Wingan Inlet Core 2: Unsupported $^{210}$Pb activity versus cumulative dry mass.
Appendix 2 ANSTO Report – Wingan Core 3
Atun Zawadzki

Project number: 2006rc0188a, 2006rc0189a
Client Organisation: Deakin University
Contacts: Dr Mark Warne
Project name: Wingan Inlet Core 3
AINSE grant number & analysis 06186 - 30 Po/Ra, 30 grain size
Number of samples received for this batch: 13 (210Pb dating), 4 (grain size)
Number of samples analysed for this batch: 7 (210Pb dating), 4 (grain size)

Background

The naturally occurring radioactive uranium-238 (238U) decays through a series of intermediates to radium-226 (226Ra) then radon-222 (222Rn) and ultimately to lead-210 (210Pb). 210Pb in turn decays to bismuth-210 (210Bi) then polonium-210 (210Po) before finally decaying to stable 206Pb. The 210Pb in sediments comprise both supported and unsupported components. The supported 210Pb is in equilibrium with all of the members of the decay chain that precede it. Unsupported 210Pb is derived from the portion of 222Rn (a noble gas) which diffuses through the soil interstitial pore space and is "lost" from its parent. The escaped 222Rn can diffuse into the atmosphere where it rapidly decays, with a half life of 3.8 days, to 210Pb which attaches to aerosol particles and settles out of the atmosphere as dry fallout or during rainfall events. This unsupported 210Pb derived from atmospheric fallout will enter the system as either direct input, falling directly into the lake or stream, or be delayed and enter the sediment as indirect input, falling elsewhere in the catchment and washed into the lake or river. In either event, once deposited and incorporated in the sediment, the activity of unsupported 210Pb will be solely a function of the amount present initially and its half life (t½ = 22.26 years) (Goldberg, 1963 and Oldfield and Appleby, 1984).

The in-situ production of supported 210Pb can be measured indirectly by measuring the activity of 226Ra using either alpha or gamma spectrometry. Unsupported 210Pb cannot be measured directly and so is inferred from the activity of total 210Pb minus the activity of supported 210Pb. The activity of total 210Pb can be determined by either measuring 210Pb directly using gamma spectrometry or measuring its progeny, 210Po (using alpha spectrometry), with which it is assumed to be in secular equilibrium.

Two 210Pb dating models are commonly used for calculating sediment rates: the CRS (constant rate of 210Pb supply) and the CIC (constant initial 210Pb concentration) models. The basic assumption of the CRS model is that the rate of supply of fallout 210Pb to the core site is constant, reflecting the constant flux of 210Pb from the atmosphere. The CIC (constant initial 210Pb concentration) model assumes that sediments in the core all had the same initial unsupported 210Pb concentration at the time they were laid down on the bed of the lake, regardless of differences in the sedimentation rate (Walling, et al., 2002).

Changes in grain size can affect the adsorption of unsupported 210Pb to sediments. Studies have shown that there can be an increase in unsupported 210Pb activity with an increase in the specific surface area of sediments (He and Walling, 1996). Therefore, the grain size distribution of sediments used for 210Pb dating need to be investigated to ascertain if there are other factors influencing the unsupported 210Pb activity other than radioactive decay.

Methodology

Samples for 210Pb dating were chemically processed using the following ANSTO methods: ENV-I-044-031 Sedimentation rate determination; ENV-I-044-006 Bulk iron removal by ether extraction; ENV-I-044-023 Polonium analysis; and ENV-I-044-027 226Ra analysis. Each dried sediment sample was spiked with 209Po and barium-133 (133Ba) yield tracers. Each sediment sample was subsequently leached with hot concentrated acids to release polonium and radium. Polonium was autoplated onto silver disks after adding the reducing agent hydroxylammonium chloride. Radium was co-precipitated with BaSO4 on a membrane filter source. The activity of the sample sources were determined by spectrometry methods.
Samples for grain size analysis were processed using the following ANSTO method: ENV-I-007-001 Particle Size Analysis using Laser Diffraction. Each wet sample was dispersed in water and pumped through a measurement chamber in a Malvern Mastersizer S laser particle analyser. The Malvern Mastersizer S uses laser diffraction to determine the particle size distribution of solids with a diameter in the range 0.05 µm to 880 µm. Solid particles outside this range are undetected.

**Spectrometry**

Sample sources were counted according to the following ANSTO method: ENV-I-044-001 Alpha spectrometry. Both the silver disk (210Po/209Po source) and membrane filter (226Ra/133Ba source) were counted by alpha spectrometry. The membrane filter was also counted by gamma spectrometry to measure 133Ba tracer activity. Chemical yield recoveries of 210Po and 226Ra were calculated using the recoveries of 209Po and 133Ba tracers.

**Results**

Table 1 shows sample descriptions, depths, cumulative dry masses and activity results. Grain size results are shown in Table 2. Table 3 shows sample depths, bulk densities, CIC and CRS calculated ages and CRS mass accumulation rates.

Total 210Pb (210Po) activities are plotted against cumulative dry mass (Fig 1) and supported 210Pb (226Ra) activities are plotted against cumulative dry mass (Fig 2). The 226Ra and 210Po activities were used to calculate unsupported 210Pb which is shown plotted against cumulative dry mass in Figure 3.

**Interpretation**

The activity of total 210Pb decreases with depth, a good indication the sediment was not mixed (see Figure 1). The activity of supported 210Pb is relatively constant over the length of the core (see Figure 2), suggesting there has been little change in local sediment input. The activity of unsupported 210Pb shows an exponential decay trend with cumulative dry mass between 0 to 7 g/cm² (0 to 11 cm depth), see Figure 3. The unsupported 210Pb activity below 7 g/cm² (11 cm) is very low and was not included in the mass accumulation rate calculations.

The unsupported 210Pb activities were plotted against cumulative dry mass on a log-linear graph. A single line of best fit through the data points between 0 to 7 g/cm² (0 to 11 cm depth) was fitted to determine the mass accumulation rate for this core using the CIC dating model. A single mass accumulation rate was calculated (see below). The age of each sediment sample was then calculated (see Table 3).

**Mass Accumulation Rate (CIC Model) for Wingan Inlet Core 3:**

\[
0.214 \pm 0.026 \text{ g/cm}^2/\text{y (Correlation Coefficient} = 0.9439) \\
\text{(calculated using unsupported 210Pb data between 0-11 cm core depth)}
\]

The CRS model mass accumulation rates and sediment ages are shown on Table 3.

Grain size distribution data is useful for normalising 210Pb data in cases where the sediment within a core consists of varying types of material (clay/mud/sand). Grain size data for every interval analysed for 210Pb is required in order to normalise the 210Pb data. Samples were not available to determine grain size as well as 210Pb from this core. Therefore, the mass accumulation rates calculated for this core were not normalised with grain size distribution.

Four samples, between 4 and 31 cm, were analysed for grain size distribution (see Table 2). The data shows the sediment material (between 4 and 31 cm) consists of about 60% mud, with the exception of the sediment interval at 10-11 cm.

**References**


### Table 1 - Wingan Inlet Core 3: Sample numbers, depths and cumulative masses, count date and total $^{210}$Pb, supported $^{210}$Pb and decay corrected unsupported $^{210}$Pb activities.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Cumulative Dry Mass (g/cm²)</th>
<th>Count Date</th>
<th>Total Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Supported Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Unsupported $^{210}$Pb (mBq/g) or (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J708</td>
<td>0.25 ± 0.25</td>
<td>0.20 ± 0.20</td>
<td>10-Feb-07</td>
<td>80.6 ± 3.1</td>
<td>9.5 ± 0.6</td>
<td>71.5 ± 3.1</td>
</tr>
<tr>
<td>J710</td>
<td>1.25 ± 0.25</td>
<td>1.03 ± 0.21</td>
<td>07-Feb-07</td>
<td>66.2 ± 2.9</td>
<td>7.5 ± 0.5</td>
<td>59.0 ± 2.9</td>
</tr>
<tr>
<td>J712</td>
<td>2.25 ± 0.25</td>
<td>1.88 ± 0.21</td>
<td>07-Feb-07</td>
<td>61.8 ± 1.7</td>
<td>6.3 ± 0.4</td>
<td>55.7 ± 1.7</td>
</tr>
<tr>
<td>J714</td>
<td>3.25 ± 0.25</td>
<td>2.62 ± 0.20</td>
<td>07-Feb-07</td>
<td>57.9 ± 1.3</td>
<td>6.8 ± 0.4</td>
<td>51.3 ± 1.4</td>
</tr>
<tr>
<td>J716</td>
<td>4.25 ± 0.25</td>
<td>3.17 ± 0.19</td>
<td>07-Feb-07</td>
<td>61.6 ± 1.4</td>
<td>7.6 ± 0.5</td>
<td>54.2 ± 1.5</td>
</tr>
<tr>
<td>J718</td>
<td>10.5 ± 0.5</td>
<td>6.65 ± 0.32</td>
<td>10-Feb-07</td>
<td>31.2 ± 0.9</td>
<td>4.8 ± 0.3</td>
<td>26.6 ± 0.9</td>
</tr>
<tr>
<td>J720</td>
<td>30.5 ± 0.5</td>
<td>20.02 ± 0.33</td>
<td>07-Feb-07</td>
<td>9.8 ± 0.4</td>
<td>7.9 ± 0.5</td>
<td>1.9 ± 0.6</td>
</tr>
</tbody>
</table>

### Table 2 - Wingan Inlet Core 3: Sample numbers, depths and grain size results for < 2 µm and < 63 µm fractions.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Mud &lt; 63 µm Content (%)</th>
<th>Clay &lt; 2 µm Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J721</td>
<td>4.5 - 5</td>
<td>60.8</td>
<td>0.5</td>
</tr>
<tr>
<td>J722</td>
<td>10 - 11</td>
<td>38.4</td>
<td>0.4</td>
</tr>
<tr>
<td>J723</td>
<td>20 - 21</td>
<td>66.4</td>
<td>0.5</td>
</tr>
<tr>
<td>J724</td>
<td>30 - 31</td>
<td>60.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Table 3 - Wingan Inlet Core 3: Sample numbers, depths, dry bulk densities, calculated CIC and CRS ages and CRS mass accumulation rates.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Dry Bulk Density (g/cm³)</th>
<th>Combined Calculated CIC Ages (years)</th>
<th>Calculated CRS Ages (years)</th>
<th>CRS Mass Accumulation Rates g/cm²/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>J708</td>
<td>0.25 ± 0.25</td>
<td>0.86</td>
<td>0.9 ± 0.9</td>
<td>0.7 ± 0.3</td>
<td>0.26 ± 0.12</td>
</tr>
<tr>
<td>J710</td>
<td>1.25 ± 0.25</td>
<td>0.81</td>
<td>4.8 ± 1.1</td>
<td>3.7 ± 0.6</td>
<td>0.28 ± 0.05</td>
</tr>
<tr>
<td>J712</td>
<td>2.25 ± 0.25</td>
<td>0.90</td>
<td>8.8 ± 1.5</td>
<td>6.7 ± 0.7</td>
<td>0.28 ± 0.03</td>
</tr>
<tr>
<td>J714</td>
<td>3.25 ± 0.25</td>
<td>0.57</td>
<td>12.2 ± 1.8</td>
<td>9.3 ± 0.8</td>
<td>0.28 ± 0.02</td>
</tr>
<tr>
<td>J716</td>
<td>4.25 ± 0.25</td>
<td>0.54</td>
<td>14.8 ± 2.0</td>
<td>11.3 ± 0.8</td>
<td>0.28 ± 0.02</td>
</tr>
<tr>
<td>J718</td>
<td>10.5 ± 0.5</td>
<td>0.57</td>
<td>31.1 ± 4.1</td>
<td>23.1 ± 1.0</td>
<td>0.29 ± 0.01</td>
</tr>
<tr>
<td>J720</td>
<td>30.5 ± 0.5</td>
<td>0.77</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1 – Wingan Inlet Core 3: Total $^{210}$Pb ($^{210}$Po) activity versus cumulative dry mass.

Figure 2 – Wingan Inlet Core 3: Supported $^{210}$Pb ($^{226}$Ra) activity versus cumulative dry mass.
Figure 3 – Wingan Inlet Core 3: Unsupported $^{210}$Pb activity versus cumulative dry mass.
Background

The naturally occurring radioactive uranium-238 ($^{238}$U) decays through a series of intermediates to radium-226 ($^{226}$Ra) then radon-222 ($^{222}$Rn) and ultimately to lead-210 ($^{210}$Pb). $^{210}$Pb in turn decays to bismuth-210 ($^{210}$Bi) then polonium-210 ($^{210}$Po) before finally decaying to stable $^{206}$Pb. The $^{210}$Pb in sediments comprise both supported and unsupported components. The supported $^{210}$Pb is in equilibrium with all of the members of the decay chain that precede it. Unsupported $^{210}$Pb is derived from the portion of $^{222}$Rn (a noble gas) which diffuses through the soil interstitial pore space and is "lost" from its parent. The escaped $^{222}$Rn can diffuse into the atmosphere where it rapidly decays, with a half life of 3.8 days, to $^{210}$Pb which attaches to aerosol particles and settles out of the atmosphere as dry fallout or during rainfall events. This unsupported $^{210}$Pb derived from atmospheric fallout will enter the system as either direct input, falling directly into the lake or stream, or be delayed and enter the sediment as indirect input, falling elsewhere in the catchment and washed into the lake or river. In either event, once deposited and incorporated in the sediment, the activity of unsupported $^{210}$Pb will be solely a function of the amount present initially and its half life ($t_{1/2} = 22.26$ years) (Goldberg, 1963 and Oldfield and Appleby, 1984).

The in-situ production of supported $^{210}$Pb can be measured indirectly by measuring the activity of $^{226}$Ra using either alpha or gamma spectrometry. Unsupported $^{210}$Pb cannot be measured directly and so is inferred from the activity of total $^{210}$Pb minus the activity of supported $^{210}$Pb. The activity of total $^{210}$Pb can be determined by either measuring $^{210}$Pb directly using gamma spectrometry or measuring its progeny, $^{210}$Po (using alpha spectrometry), with which it is assumed to be in secular equilibrium.

Two $^{210}$Pb dating models are commonly used for calculating sediment rates: the CRS (constant rate of $^{210}$Pb supply) and the CIC (constant initial $^{210}$Pb concentration) models. The basic assumption of the CRS model is that the rate of supply of fallout $^{210}$Pb to the core site is constant, reflecting the constant flux of $^{210}$Pb from the atmosphere. The CIC (constant initial $^{210}$Pb concentration) model assumes that sediments in the core all had the same initial unsupported $^{210}$Pb concentration at the time they were laid down on the bed of the lake, regardless of differences in the sedimentation rate (Walling, et al., 2002).

Changes in grain size can affect the adsorption of unsupported $^{210}$Pb to sediments. Studies have shown that there can be an increase in unsupported $^{210}$Pb activity with an increase in the specific surface area of sediments (He and Walling, 1996). Therefore, the grain size distribution of sediments used for $^{210}$Pb dating need to be investigated to ascertain if there are other factors influencing the unsupported $^{210}$Pb activity other than radioactive decay.

Methodology

Samples for $^{210}$Pb dating were chemically processed using the following ANSTO methods: ENV-I-044-031 Sedimentation rate determination; ENV-I-044-006 Bulk iron removal by ether extraction; ENV-I-044-023 Polonium analysis; and ENV-I-044-027 $^{226}$Ra analysis.

Each dried sediment sample was spiked with $^{209}$Po and barium-133 ($^{133}$Ba) yield tracers. Each sediment sample was subsequently leached with hot concentrated acids to release polonium and radium. Polonium was autoplated onto silver disks after adding the reducing agent hydroxylammonium chloride. Radium was co-precipitated with BaSO$_4$ on a membrane filter source. The activity of the sample sources were determined by spectrometry methods.

Samples for grain size analysis were processed using the following ANSTO method: ENV-I-007-001 Particle Size Analysis using Laser Diffraction. Each wet sample was dispersed in water and pumped through a...
measurement chamber in a Malvern Mastersizer S laser particle analyser. The Malvern Mastersizer S uses laser diffraction to determine the particle size distribution of solids with a diameter in the range 0.05 µm to 880 µm. Solid particles outside this range are undetected.

**Spectrometry**

Sample sources were counted according to the following ANSTO method: ENV-I-044-001 Alpha spectrometry. Both the silver disk (210Po/209Po source) and membrane filter (226Ra/133Ba source) were counted by alpha spectrometry. The membrane filter was also counted by gamma spectrometry to measure 133Ba tracer activity. Chemical yield recoveries of 210Po and 226Ra were calculated using the recoveries of 209Po and 133Ba tracers.

**Results**

Table 1 shows sample descriptions, depths, cumulative dry masses and activity results. Grain size results are shown in Table 2. Table 3 shows sample depths, bulk densities, CIC and CRS calculated ages and CRS mass accumulation rates.

Total 210Pb (210Po) activities are plotted against cumulative dry mass (Fig 1) and supported 210Pb (226Ra) activities are plotted against cumulative dry mass (Fig 2). The 226Ra and 210Po activities were used to calculate unsupported 210Pb which is shown plotted against cumulative dry mass in Figure 3.

**Interpretation**

The overall activity of total 210Pb in this core decreases with depth (see Figure 1), excluding the bottom sample. The activities of supported 210Pb slightly decreases with depth (see Figure 2), suggesting there may be a slight change in local sediment input, in particular at the bottom of the core. The activities of unsupported 210Pb in the top 13 cm (6.8 g/cm²) of the core do not show a decay trend with depth, suggesting the sediment layers may be mixed (and/or disturbed). Between 13 and 58 cm the unsupported 210Pb activities show a decay trend with depth. The mass accumulation rates for this core were calculated using unsupported 210Pb data between 13 and 58 cm (6.8 and 58.8 g/cm²) only.

The unsupported 210Pb activities were plotted against cumulative dry mass on a log-linear graph. A single line of best fit through the data points between 13 and 58 cm (6.8 and 58.8 g/cm²) was fitted to determine the mass accumulation rate for this core using the CIC dating model. A single mass accumulation rate was calculated (see below). It was assumed the calculated mass accumulation rate applies to the top 13 cm of the sediment core. The age of each sediment sample was then calculated (see Table 3).

**Mass Accumulation Rate (CIC Model) for Wingan Inlet Core 5:**

0.84 ± 0.26 g/cm²/y (Correlation Coefficient = 0.6802)  
(calculated using unsupported 210Pb data between 13-58 cm core depth)

The CRS model mass accumulation rates and sediment ages are shown on Table 3, also calculated using unsupported 210Pb data between13-58 cm only.

Grain size distribution data is useful for normalising 210Pb data in cases where the sediment within a core consists of varying type of materials (clay/mud/sand). The grain size data for this core (see Table 2) suggests the sediment in the core consists of the same type of material. Therefore, grain size data were not used to normalise the unsupported 210Pb data for this core, in calculating the mass accumulation rates.

**References**


Table 1 - Wingan Inlet Core 5: Sample numbers, depths and cumulative masses, count date and total $^{210}\text{Pb}$, supported $^{210}\text{Pb}$ and decay corrected unsupported $^{210}\text{Pb}$ activities.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Cumulative Dry Mass (g/cm$^2$)</th>
<th>Count Date</th>
<th>Total Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Supported Pb-210 (mBq/g) or (Bq/kg)</th>
<th>Unsupported $^{210}\text{Pb}$ Corrected to reference date (mBq/g) or (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J509</td>
<td>0.5 ± 0.5</td>
<td>0.1 ± 0.1</td>
<td>23-Oct-06</td>
<td>59.3 ± 1.8</td>
<td>7.3 ± 0.5</td>
<td>52.1 ± 1.8</td>
</tr>
<tr>
<td>J678</td>
<td>1.5 ± 0.5</td>
<td>0.3 ± 0.1</td>
<td>20-Jan-07</td>
<td>46.1 ± 2.0</td>
<td>6.1 ± 0.5</td>
<td>40.4 ± 2.1</td>
</tr>
<tr>
<td>J510</td>
<td>2.5 ± 0.5</td>
<td>0.5 ± 0.1</td>
<td>23-Oct-06</td>
<td>57.6 ± 1.7</td>
<td>8.7 ± 0.7</td>
<td>49.0 ± 1.8</td>
</tr>
<tr>
<td>J679</td>
<td>3.5 ± 0.5</td>
<td>0.9 ± 0.1</td>
<td>20-Jan-07</td>
<td>57.8 ± 1.5</td>
<td>6.3 ± 0.5</td>
<td>52.0 ± 1.5</td>
</tr>
<tr>
<td>J511</td>
<td>4.5 ± 0.5</td>
<td>1.2 ± 0.1</td>
<td>23-Oct-06</td>
<td>57.5 ± 1.3</td>
<td>7.5 ± 0.6</td>
<td>50.1 ± 1.4</td>
</tr>
<tr>
<td>J680</td>
<td>5.5 ± 0.5</td>
<td>1.6 ± 0.1</td>
<td>20-Jan-07</td>
<td>44.7 ± 1.4</td>
<td>7.5 ± 0.6</td>
<td>37.5 ± 1.5</td>
</tr>
<tr>
<td>J512</td>
<td>6.5 ± 0.5</td>
<td>2.1 ± 0.2</td>
<td>23-Oct-06</td>
<td>63.2 ± 2.8</td>
<td>7.7 ± 0.6</td>
<td>55.6 ± 2.8</td>
</tr>
<tr>
<td>J681</td>
<td>7.5 ± 0.5</td>
<td>2.7 ± 0.2</td>
<td>05-Feb-07</td>
<td>41.1 ± 0.9</td>
<td>5.0 ± 0.4</td>
<td>36.5 ± 1.0</td>
</tr>
<tr>
<td>J513</td>
<td>8.5 ± 0.5</td>
<td>3.4 ± 0.2</td>
<td>23-Oct-06</td>
<td>47.3 ± 1.5</td>
<td>6.4 ± 0.5</td>
<td>40.9 ± 1.6</td>
</tr>
<tr>
<td>J514</td>
<td>13.5 ± 0.5</td>
<td>6.8 ± 0.3</td>
<td>16-Dec-06</td>
<td>52.3 ± 2.2</td>
<td>7.9 ± 0.6</td>
<td>44.7 ± 2.3</td>
</tr>
<tr>
<td>J515</td>
<td>18.5 ± 0.5</td>
<td>10.0 ± 0.3</td>
<td>16-Dec-06</td>
<td>28.9 ± 1.2</td>
<td>5.5 ± 0.4</td>
<td>23.5 ± 1.3</td>
</tr>
<tr>
<td>J516</td>
<td>23.5 ± 0.5</td>
<td>14.1 ± 0.3</td>
<td>16-Dec-06</td>
<td>13.8 ± 0.5</td>
<td>4.4 ± 0.3</td>
<td>9.48 ± 0.6</td>
</tr>
<tr>
<td>J517</td>
<td>28.5 ± 0.5</td>
<td>18.4 ± 0.3</td>
<td>19-Dec-06</td>
<td>13.9 ± 0.5</td>
<td>4.8 ± 0.4</td>
<td>9.12 ± 0.6</td>
</tr>
<tr>
<td>J518</td>
<td>33.5 ± 0.5</td>
<td>23.1 ± 0.3</td>
<td>23-Oct-06</td>
<td>13.4 ± 0.5</td>
<td>3.8 ± 0.4</td>
<td>9.63 ± 0.6</td>
</tr>
<tr>
<td>J519</td>
<td>38.5 ± 0.5</td>
<td>28.7 ± 0.4</td>
<td>08-Jan-07</td>
<td>11.1 ± 0.5</td>
<td>3.6 ± 0.3</td>
<td>7.54 ± 0.6</td>
</tr>
<tr>
<td>J523</td>
<td>58.5 ± 0.5</td>
<td>58.8 ± 0.5</td>
<td>23-Oct-06</td>
<td>8.2 ± 0.3</td>
<td>4.2 ± 0.5</td>
<td>4.02 ± 0.5</td>
</tr>
<tr>
<td>J528</td>
<td>83.5 ± 0.5</td>
<td>95.9 ± 0.6</td>
<td>23-Oct-06</td>
<td>9.9 ± 0.8</td>
<td>0.04 ± 0.10</td>
<td>9.92 ± 0.8</td>
</tr>
</tbody>
</table>

Table 2 - Wingan Inlet Core 5: Sample numbers, depths and grain size results for < 2 µm and < 63 µm fractions.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>ANSTO ID</th>
<th>Clay Content (%)</th>
<th>Mud Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J533</td>
<td>0 - 1</td>
<td>J509</td>
<td>4.3</td>
<td>85.0</td>
</tr>
<tr>
<td>J534</td>
<td>2 - 3</td>
<td>J510</td>
<td>2.8</td>
<td>74.6</td>
</tr>
<tr>
<td>J535</td>
<td>4 - 5</td>
<td>J511</td>
<td>3.0</td>
<td>82.4</td>
</tr>
<tr>
<td>J536</td>
<td>6 - 7</td>
<td>J512</td>
<td>3.3</td>
<td>77.3</td>
</tr>
<tr>
<td>J537</td>
<td>8 - 9</td>
<td>J513</td>
<td>3.1</td>
<td>82.0</td>
</tr>
<tr>
<td>J542</td>
<td>33 - 34</td>
<td>J518</td>
<td>3.9</td>
<td>84.6</td>
</tr>
<tr>
<td>J547</td>
<td>58 - 59</td>
<td>J523</td>
<td>7.4</td>
<td>91.9</td>
</tr>
<tr>
<td>J552</td>
<td>83 - 84</td>
<td>J528</td>
<td>7.4</td>
<td>92.4</td>
</tr>
</tbody>
</table>
Table 3 - *Wingan Inlet Core 5*: Sample numbers, depths, dry bulk densities, calculated CIC and CRS ages and CRS mass accumulation rates.

<table>
<thead>
<tr>
<th>ANSTO ID</th>
<th>Depth (cm)</th>
<th>Dry Bulk Density (g/cm³)</th>
<th>Combined Calculated CIC Ages (years)</th>
<th>Calculated CRS Ages (years)</th>
<th>Mass Accumulation Rates g/cm²/y</th>
</tr>
</thead>
</table>
Figure 1 – Wingan Inlet Core 5: Total $^{210}$Pb ($^{210}$Po) activity versus cumulative dry mass.

Figure 2 – Wingan Inlet Core 5: Supported $^{210}$Pb ($^{226}$Ra) activity versus cumulative dry mass.
Figure 3 – Wingan Inlet Core 5: Unsupported $^{210}$Pb activity versus cumulative dry mass.
Appendix 4 Report on ostracod specimens in Wingan Cores 2, 3 & 5.
Mark Warne

Key
Very Abundant - VA (> 100 adult and juvenile specimens)
Abundant - A (50 – 100 adult and juvenile specimens)
Common - C (10 – 50 adult and juvenile specimens)
Rare - R (< 10 adult or juvenile specimens)

Wingan Inlet Core 2
Sample sizes = 3 cms slice of 5 cm diameter core.

Sample MFS 1 (93 – 96 cms down from top of core).
~ 900 specimens
Osticythere baragwanathi VA
Paracytheroma sudaustrialis A
Loxocycthere hornibrooki C
Ponticocycthereis militaris VA
Semicytherura cf. illerti R
Leptocythere hartmanni C
Xestoleberis cedunaensis C
Mckenziartia portjacksonensis C
Paracypria maryboroughensis R
Loxoconcha sp. R
Echinocythereis sp. R
Semicytherura sp. R
Microcythere sp. R
Actinocythereis robusta R
Indeterminate spp. R

Sample MFS 4 (60 – 63 cms down from top of core).
~ 600 specimens
Osticythere baragwanathi VA
Paracytheroma sudaustrialis A
Loxocycthere hornibrooki C
Ponticocycthereis militaris VA
Semicytherura cf. illerti R
Leptocythere hartmanni C
Xestoleberis cedunaensis C
Mckenziartia portjacksonensis C
Paracypria maryboroughensis R
Yassinicythere bassiounii R
Indeterminate spp. R

Sample MFS 7 (30 – 33 cms down from top of core).
~ 320 specimens
Osticythere baragwanathi VA
Paracytheroma sudaustrialis C
Loxocycthere hornibrooki R
Ponticocycthereis militaris A
Semicytherura cf. illerti R
Leptocythere hartmanni C
Xestoleberis cedunaensis C
Paracypria maryboroughensis R
Semicytherura sp. R
Xestoleberis sp. R
Microcythere sp. R
Yassinicythere bassiounii R
Indeterminate spp. R
Sample MFS 9 (10 – 13 cms down from top of core).
~ 280 specimens
Osticythere baragwanathi VA
Paracytheroma sudoaustralis C
Ponticocythereis militaris C
Semicytherura cf. illerti R
Xestoleberis cedunaensis R
Paracypria maryboroughensis R
Semicytherura sp. R
Xestoleberis spp. R
Yassinicythere bassiounii R
Indeterminate spp. R

Sample MFS 10 (6 – 9 cms down from top of core).
~ 70 specimens
Osticythere baragwanathi C
Paracytheroma sudoaustralis C
Semicytherura cf. illerti R
Leptocythere hartmanni R
Paracypria maryboroughensis R
Semicytherura sp. R
Indeterminate spp. R

Wingan Inlet Core 3
Sample sizes = 3 cms slice of 5 cm diameter core.

Sample MFS 1 (26 – 29 cms down from top of core).
~ 750 specimens
Osticythere baragwanathi VA
Paracytheroma sudoaustralis A
Loxocythere hornibrooki C
Ponticocythereis militaris VA
Semicytherura cf. illerti R
Leptocythere hartmanni C
Xestoleberis cedunaensis C
Loxoconcha sp. R
Semicytherura spp. R
Microcytherura sp. R
Xestoleberis sp. R
Yassinicythere bassiounii R
Indeterminate spp. R

Sample MFS 2 (16 – 19 cms down from top of core).
~ 13 specimens
Osticythere baragwanathi R
Paracytheroma sudoaustralis R
Loxocythere hornibrooki R
Ponticocythereis militaris R
Semicytherura cf. illerti R
Leptocythere hartmanni R
Paracypria maryboroughensis R
Indeterminate spp. R

Sample MFS 3 (6 – 9 cms down from top of core).
1 specimen
Ponticocythereis militaris R
Wingan Inlet Core 5
Sample sizes = 3 cms slice of 10 cm diameter core.

Sample MFS A (105 – 108 cms down from top of core).
No ostracod specimens, but abundant macroscopic shell material.

Sample MFS I (65 – 68 cms down from top of core).
No ostracod specimens.

Sample MFS P (30 – 33 cms down from top of core).
1 specimen
Paracytheroma sudastralis R

Sample MFS T (65 – 68 cms down from top of core).
No ostracod specimens.

Sample MFS U (9 – 10 cms down from top of core).
No ostracod specimens.