



**Cardno
Ecology Lab**

Shaping the Future

Marine and Freshwater Studies



Ex HMAS Adelaide Artificial Reef Sediment Quality Monitoring Survey 3

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Cover Image: Ex HMAS Adelaide Survey Site June 2016, Cardno Ecology Lab.

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Executive Summary

The Ex-HMAS Adelaide was gifted from the Australian to the NSW Government for the specific purpose of scuttling the ship as an artificial dive reef off the Central Coast of NSW. In accordance with the Artificial Reef (Sea dumping) permit, the NSW Department of Primary Industries - Lands, were required to implement a Long Term Monitoring and Management Plan (LTMMP), which was prepared by Worley Parsons in March 2011.

The LTMMP covers environmental and structural monitoring for the first five years post-scuttling and forms the basis for ongoing monitoring and maintenance over the operational life of the vessel as a dive site, which is estimated to be approximately 40 years. Part of the LTMMP involves the monitoring of marine sediments in and around the ship to examine how metal corrosion and degradation of protective paint layers over time may impact on the surrounding marine environment and benthic biota.

Sediments were collected using a stainless steel benthic Van Veen grab deployed from a vessel at control and monitoring locations. As per the requirements of the LTMMP, sediment samples were tested for aluminium, iron, chromium, copper, lead, nickel and zinc and sediment particle size distribution. Due to recent legislations and diving restrictions, sediments were not sampled from within the hull of the ship itself.

Results of the June 2016 study showed that in general, metal concentrations recorded 62 months post-scuttling were similar to those recorded after only one month post-scuttling (May 2011) and therefore, did not indicate any significant long-term effects attributed to the ship. The exception to this was for aluminium, which showed an overall increase in concentrations at impact sites 62 months post-scuttling in comparison with that recorded 1 month post-scuttling. This increase appeared to be greater at the impact location compared to the control location (in June 2016), although this difference was not statistically significant. Aluminium is also naturally present in the marine environment and fluctuations may also be due to natural variability or diffuse inputs following storm events. In the absence of sediment quality guideline values (SQGVs) and paucity of information on background levels in marine sediments, it is difficult to understand at what concentrations aluminium would be expected to have impacts on marine biota. This may be addressed by adopting a multiple lines of evidence approach in any future investigations.

For metals where ANZECC/ARMCANZ (2000) interim sediment quality guidelines (ISQG) are available (i.e. for chromium, copper, nickel, lead and zinc), concentrations were all well below the ISQG lower trigger values and were not therefore considered to represent a contamination risk to the marine environment.

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Glossary

Artificial Reef	A structure or formation placed on the seabed for the purpose of increasing or concentrating populations of marine plants and animals or for the purpose of being used in human recreational activities.
ANZECC/ARMCANZ	Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.
Bioaccumulation	The accumulation of substances, such as pesticides or heavy metals in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is eliminated.
Biomagnification	Where animals feeding on bioaccumulators have a diet enriched with these substances. If unable to excrete them they acquire an even greater body burden of the substance.
DoE	Department of the Environment (formerly DSEWPaC)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EP&A Act	Environmental Planning & Assessment Act 1979.
ISQG	Interim Sediment Quality Guideline.
LAT	Lowest Astronomical Tide.
LTMMMP	Long Term Management and Monitoring Plan.

1 Introduction

1.1 Background and Aims

Cardno (NSW/ACT) Pty Ltd was commissioned by the NSW Department of Primary Industries – Lands, to undertake the post-scuttling environmental monitoring for the Ex-HMAS Adelaide artificial reef and dive site.

The Ex-HMAS Adelaide was gifted from the Australian to the NSW Government for the specific purpose of scuttling the ship as an artificial reef off the Central Coast of NSW. A comprehensive environmental assessment was undertaken for the project in accordance with state and federal environmental legislation. This included approval under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and obtaining an Artificial Reef (or Sea Dumping) Permit issued under the *Environment Protection (Sea Dumping) Act 1981* from the federal Department for Sustainability, Environment, Water, Population and Communities (DSEWPaC), currently the Department of the Environment (DoE).

Sea Dumping Permits ensure that appropriate placement sites are selected, materials are suitable and appropriately prepared, that there are no significant adverse impacts on the marine environment and that the reef does not pose a danger to marine users. A condition of the Permit was that DPI Lands must implement the proposed Long Term Monitoring and Management Plan (LTMMP) which was prepared by Worley Parsons in March 2011.

The LTMMP covers environmental and structural monitoring for the first five years post-scuttling and forms the basis for ongoing monitoring and maintenance over the operational life of the vessel as a dive site, which is estimated to be approximately 40 years. The frequency of monitoring and the methodologies used are to be reviewed periodically during the life of the Plan. The LTMMP includes the following environmental monitoring components:

- Reef communities;
- Sediment quality; and
- Bioaccumulation studies.

The aim of the sediment quality monitoring survey, as outlined in the LTMMP, was to gain an understanding of how metal corrosion and degradation of paint layers may be influencing/impacting on the marine environment and whether benthic organisms are likely to be affected by metal enrichment. The LTMMP stipulates that sediment testing is carried out for the following metals:

- Aluminium;
- Iron;
- Chromium;
- Copper;
- Lead;
- Nickel; and
- Zinc.

Baseline sediment sampling was undertaken in 2009 by Worley Parsons (2009) and 1 month post-scuttling in May 2011 (Worley Parsons 2011). In accordance with the LTMMP subsequent surveys were undertaken by Cardno 6 months post-scuttling in October 2011 (Survey 1) and 21 months post-scuttling in January 2013 (Survey 2). This Progress Report outlines the methodology and findings of the 62 month post-scuttling sediment sampling undertaken by Cardno in June 2016 (Survey 3).

This progress report outlines the following:

- Description of sampling dates, times, weather conditions and tidal height;
- Description of the methods used to retrieve sediment samples;
- Results and interpretation of laboratory analyses;
- Discussion of findings; and
- Reports of any condition or occurrence that may influence results of the study.

Sediment quality results were compared with ANZECC/ARMCANZ (2000) sediment quality guidelines and previous results for control sites. As required by the monitoring condition set by the Administrative Appeals

Tribunal, sediment from two sites within the hull were also to be sampled and analysed for lead to measure any changes in sediment lead concentrations over time. The location of the monitoring sites are in the bottom centre of the Laundry (compartment number 4-140-0-Q); and Auxiliary Machinery Room Number 3 (compartment number 5-292-0-L). This component of the study could not however, be carried out at this time due to changes in diving legislation and occupational diving health and safety requirements.

1.2 Study Site and Nature of Contaminants

The Ex-HMAS Adelaide artificial reef and dive site is located within Bulbararing Bay, approximately 1.87 km offshore from Avoca Beach. The ship lies at a depth of approximately 32 m to 34 m of water at Lowest Astronomical Tide (LAT) on top of a relatively flat, sandy substratum. There is a minimum of 6 m of sand overlying bedrock. The vessel is orientated with the bow facing into the prevailing ESE swell direction (**Figure 1**).

The ship is 138.1 m in length, with a beam of 14.3 m and an original displacement of 4,200 tonnes. The hull is made of steel and the superstructure of aluminium alloy. Heights are approximately 12 m to the main deck, 18 m to the bridge, 24 m to the top of the foremast (the mast closest to the bow), and 39 m to the top of the mainmast (NSW Government 2011). The ship was prepared for scuttling by McMahon's Services. This involved the removal of the main mast structures for safety and navigation reasons and stripping of machinery, hatches and any items that could pose a risk to divers or the environment. Potential contaminants such as fuels, oils, heavy metals, batteries and electrical items containing polychlorinated biphenols (PCBs) were removed. Diver access holes have been cut into the sides of the hull, floors and ceilings to allow extra vertical access between decks and also to allow light to penetrate. Further holes were also made to allow air to escape during the scuttling process (NSW Government 2011).

The Ex-HMAS Adelaide was prepared to meet DSEWPaC standards which were specified during the months of preparation prior to scuttling. DSEWPaC had conducted a series of inspections to confirm that its detailed requirements were achieved. The original clean-up process included removing loose or flaking paint in accordance with DSEWPaC's requirements. A total of 110 paint locations were then tested from representative locations across the ship, confirming the presence of lead primer at some locations on the steel lower decks of the ship. The paint at other locations tested had yellow primer, red oxide, white topcoat and grey topcoat which did not contain lead. The use of lead-based primer is only relevant to the internal steel hull and lower decks of the ship where it was used for corrosion protection, as the superstructure is constructed of aluminium.

Environmental risk experts concluded that the risks to the environment and human health from the presence of lead-based primer are negligible because the lead primer used is in the form of lead tetroxide, which is very insoluble so there would be minimal leaching. The lead is also in a form that has low bioavailability, little potential for bioaccumulation, and does not biomagnify. Risks due to copper in the anti-fouling paint are not a significant concern because the coating is designed to leach as part of its protective process and the leaching rate declines after the first six months. Because of this declining rate, the Navy's standard practice is to apply a new coating every five years and the last coating was applied to the Adelaide seven years prior to scuttling, so it is therefore near the end of its useful life, thus reducing the amount of copper remaining that could be released into the marine environment.

1.3 Previous Studies

1.3.1 Baseline Survey

During the baseline survey (Worley Parsons 2009) marine sediments were collected from three sites in the approximate location in which the Ex-HMAS Adelaide would be scuttled (V1, V2 and V3). Concentrations of all metals in the baseline survey were less than their respective ANZECC / ARMCANZ (2000) ISQG-Low values (where these had been established). As these were taken from locations different to those in subsequent surveys (as specified in the LTMMP), these were not considered appropriate 'baseline' samples for comparison with later surveys but are useful in providing context of the broader conditions within the study area.

1.3.2 1 Month Post Scuttling

One month post-scuttling, the concentrations of metals in sediment at all control and monitoring (impact) sites (as specified in the LTMMP) were below the ISQG-Low values and similar to the concentrations found at sites V1, V2 and V3 during the baseline survey, indicating that there was a low risk that any adverse biological effects would

occur to marine organisms living within the sediments surrounding the Ex-HMAS Adelaide (Worley Parsons 2011).

1.3.3 6 Months Post-Scuttling

A further investigation was carried out 6 months post-scuttling (Cardno Ecology Lab 2011). Results of that investigation indicated that six months post-scuttling, there were no appreciable increases in the concentrations of the metals tested in marine sediments adjacent to the ship and that for many of the metals analysed (aluminium, chromium, iron, nickel and zinc), concentrations were lower than in previous surveys. Sediments tested from within the hull of the ship did not indicate any significant lead contamination.

1.3.4 21 Months Post-Scuttling

The results of the sediment quality survey undertaken 21 months post-scuttling did not show any notable increase in the concentrations of the metals tested (aluminium, chromium, copper, iron, nickel, lead and zinc) in marine sediments adjacent to the ship (Cardno Ecology Lab 2013). For many of the metals analysed (aluminium, chromium, iron, lead and zinc), mean concentrations were marginally higher than in previous surveys, while mean concentrations of copper had decreased and concentrations of nickel remained the same. Based on these findings, impact to the marine environment and associated benthic biota as a result of metal corrosion and/or degradation of paint layers from the Ex-HMAS Adelaide was considered unlikely.



Boundary of Dive Site	Easting (MGA 94)	Northing (MGA 94)
A	356428.713	6296117.693
B	356538.438	6296341.142
C	356850.615	6296188.618
D	356742.410	6295963.310

Figure 1: Location of Ex-HMAS Adelaide Artificial Reef and Dive Site. The approximate location and orientation of the ship is indicated by the yellow line.

2 Study Methods

2.1 Sampling Sites

Samples for Survey 3 were collected from the same sites as those pre-determined by the LTMMMP in the earlier (one month post-scuttling survey) and subsequent monitoring surveys. These included a total of nine samples with three control locations (S2, S3 and S6) and six monitoring locations (I1, I2, I3, I4, I5 and I6). For continuity, the same location ID's as previous surveys were used. Locations and GPS positions of the nine sampling locations are given in **Table 1** and **Figure 2**.

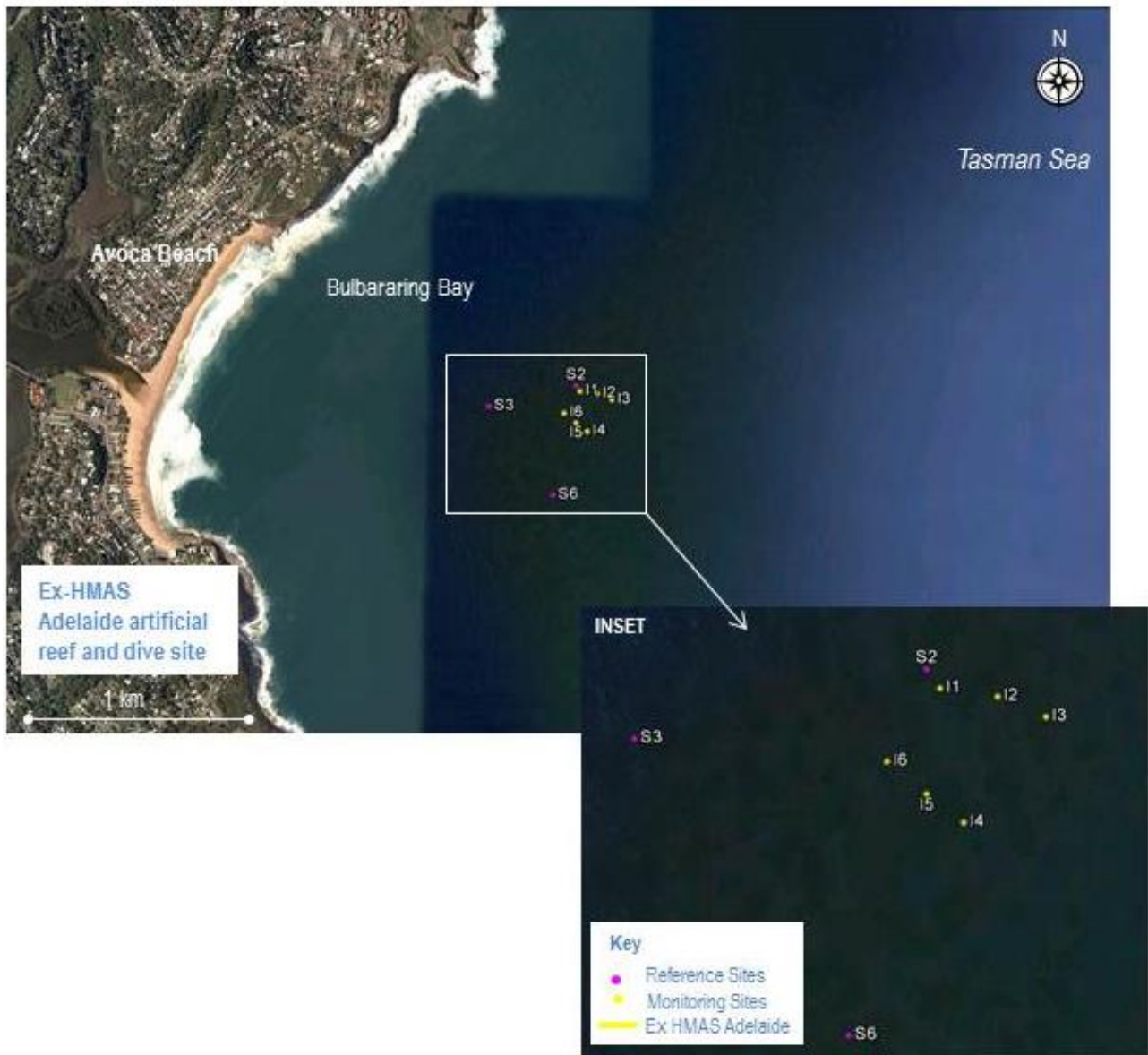


Figure 2: Locations of Marine Sediment Quality Sampling Sites

Table 1: GPS Positions of Marine Sediment Quality Sampling Sites (Coordinates are in MGA 94)

Sample Point	Latitude (S)	Longitude (E)
Control Site - S2*	33°27.829'	151°27.416'
Control Site - S3	33°27.880'	151°27.157'
Control Site - S6	33°28.099'	151°27.347'
Monitoring Site - I1	33°27.843'	151°27.428'
Monitoring Site- I2	33°27.849'	151°27.479'
Monitoring Site - I3	33°27.864'	151°27.522'
Monitoring Site - I4	33°27.942'	151°27.449'
Monitoring Site - I5	33°27.921'	151°27.416'
Monitoring Site - I6	33°27.897'	151°27.381'

*Due to the proximity to the ship, this site was analysed as a monitoring site in June 2016, not a control site.

2.2 Sampling Methodology

2.2.1 Field Methods

Sediment samples from monitoring locations in the vicinity of the Ex-HMAS Adelaide and at control locations were collected on 10 June 2016. Sediment samples were collected by deploying a stainless steel Van Veen benthic grab from a boat. The sampler collects approximately 2 L of sediment. At each site, co-ordinates were recorded using GPS (accurate to < 5 m). Approximately 500 g of sediment was extracted from each grab, transferred into a polyurethane zip-lock bag and chilled in an esky. After each sample was collected, the grab was inverted and rinsed with a jet of water to avoid cross-contamination of samples. Samples were also collected for analysis of particle size distribution. Each sample was clearly labelled internally and externally, with the project details, time, date, location, site and replicate number. Samples were refrigerated at 4°C overnight then sent by courier to ALS laboratories (an NATA accredited laboratory), Sydney for processing.

2.2.2 Laboratory Methods

Sediment samples were tested for trace metals aluminium (Al), iron (Fe), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) against NODG (National Ocean Disposal Guideline for Dredged Material 2002) and ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines.

Sediment samples were prepared by 'Hot Block Digest' for metals in soils, sediments and sludges and tumbler extraction of solids/sample clean up. Moisture content was calculated by a gravimetric procedure based on weight loss over a 12 hour drying period at 103 – 105°C. Total metals in sediments were calculated by the ICPMS (Inductively Coupled Plasma Mass Spectrometry) technique which uses argon plasma to ionise selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. 1g of sample is leached at room temperature for 1 hour in 10% hydrochloric acid. The resultant extract is filtered and bulked for analysis of extracted metals.

Sediments for particle size analyses were tested using the dry sieve method (AS 1289.3.6.11-1995), yielding the distribution of particles sizes greater than 0.075 mm and median grain size. Sediment particle sizes less than 0.075 mm were also analysed using the hydrometer method to describe fine particle sizes down to 1 – 5 µm according to AS 1289 3.6.3.

2.3 Analyses

Sediment concentrations were reported as means with standard deviations from the mean. Contaminant data were compared with the Interim Sediment Quality Guideline (ISQG) values as per ANZECC/ARMCANZ (2000). These values assist in identifying conditions where adverse biological effects may be observed as well as acting as triggers for the implementation of management actions or for additional site-specific studies.

Metal concentrations at monitoring sites (I1 – I6) were compared with concentrations at control locations (S2, S3 and S6) and also compared among survey times: baseline, one month post-scuttling, 6 months post-scuttling, 21 months post-scuttling and the current survey (62 months post-scuttling). Where appropriate, univariate analyses were undertaken using Primer v6 software.

2.4 Assumptions and Limitations

Location S2 was not considered to be appropriate as a control location due to its close proximity to the ship and other monitoring locations. This was therefore treated as a monitoring site in considering the overall results.

3 Results

Concentrations of metal contaminants in sediment samples are provided in **Table 2** and **Figure 3**. Raw lab data is provided in **Appendix 1**. The main findings are summarised as follows:

- Aluminium

Mean concentrations of Al detected 62 months post-scuttling (June 2016) was greater than the levels detected during all other surveys in samples collected from both control and impact sites. The mean Al concentration in samples collected during the June 2016 survey was also greater in the impact sites in comparison with the control sites, although a large difference in Al concentrations between control sites S3 and S6, contributed to a large S.E. within the control treatment and this difference was not therefore statistically significantly different. No ANZECC/ARMCANZ (2000) guidelines apply to Al in marine sediments.

- Chromium

Mean concentrations of Cr detected 62 months post-scuttling (June 2016), was similar to that recorded one month post-scuttling (May 2011) in both control and impact locations despite an overall decrease during surveys carried out 6 (Oct 2011) and 21 months (Jan 2013) post-scuttling. Concentrations of Cr were well below the ANZECC/ARMCANZ (2000) ISQG lower trigger value of 80 mg/kg in all surveys.

- Copper

Mean concentrations of Cu detected 62 months post-scuttling (June 2016) was similar to that recorded one month post-scuttling (May 2011) despite an overall decrease during surveys carried out 6 (Oct 2011) and 21 months (Jan 2013) post-scuttling. Concentrations of Cu were well below the ANZECC/ARMCANZ (2000) ISQG lower trigger value of 60 mg/kg in all surveys.

- Iron

Mean concentrations of Fe detected 62 months post-scuttling (June 2016), was similar to that recorded one month post-scuttling (May 2011) in both control and impact locations despite an overall decrease during surveys carried out 6 (Oct 2011) and 21 months (Jan 2013) post-scuttling. No ANZECC/ARMCANZ (2000) guidelines apply to Al in marine sediments.

- Nickel

Mean concentrations of Ni detected 62 months post-scuttling (June 2016), was similar to that recorded one month post-scuttling (May 2011) in both control and impact locations despite an overall decrease during surveys carried out 6 (Oct 2011) and 21 months (Jan 2013) post-scuttling. Concentrations of Ni were well below the ANZECC/ARMCANZ (2000) ISQG lower trigger value of 21 mg/kg in all surveys.

- Lead

Mean concentrations of Pb detected 62 months post-scuttling (June 2016), was slightly lower than that recorded one month post-scuttling (May 2011) at the impact location and slightly higher at the control location. Concentrations of Pb were well below the ANZECC/ARMCANZ (2000) ISQG lower trigger value of 50 mg/kg in all surveys.

- Zinc

Mean concentrations of Zn detected 62 months post-scuttling (June 2016), was similar to that recorded one month post-scuttling (May 2011) in both control and impact locations despite an overall decrease during surveys carried out 6 (Oct 2011) and 21 months (Jan 2013) post-scuttling. Concentrations of Zn were well below the ANZECC/ARMCANZ (2000) ISQG lower trigger value of 200 mg/kg in all surveys.

- Particle Size Analysis

Particle size in sediments collected from all sites was relatively uniform, consisting of between 98 and 99% sand (0.06-2.00 mm) and 1- 2% silt and clay (>2 - 60µm).

Table 2: Heavy Metal Concentrations Recorded in Sediment Samples Collected from Monitoring and Control Locations during May 2011 (one month post-scuttling), October 2011 (six months post-scuttling), January 2013 (21 months post-scuttling) and June 2016 (62 months post scuttling). Where the metal concentration was below the LOR (Level of Reporting), it was treated as a zero value. Values exceeding ANZECC/ARMCANZ (2000) ISQG guideline levels are highlighted where applicable.

		Aluminium (mg/kg)				Chromium (mg/kg)				Copper (mg/kg)				Iron (mg/kg)				Nickel (mg/kg)				Lead (mg/kg)				Zinc (mg/kg)							
		n/a				80 - 370				65 - 270				n/a				21 - 52				50 - 220				200 - 410							
		Months Post-Scuttling				Months Post-Scuttling				Months Post-Scuttling				Months Post-Scuttling				Months Post-Scuttling				Months Post-Scuttling				Months Post-Scuttling							
		1	6	21	62	1	6	21	62	1	6	21	62	1	6	21	62	1	6	21	62	1	6	21	62	1	6	21	62	1	6	21	62
Sample ID		May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016	May 2011	Oct 2011	Jan 2013	June 2016
Control	S3	1100.0	160.0	200.0	2470.0	6.9	1.3	1.6	8.2	1.7	0.0	0.0	1.9	10000.0	1080.0	1280.0	10900.0	2.5	0.0	0.0	3.1	3.1	2.2	2.9	3.8	10.0	2.3	3.4	12.0				
	S6	740.0	110.0	100.0	740.0	6.0	1.0	1.0	6.4	0.8	0.0	0.0	0.0	7300.0	960.0	770.0	7200.0	1.5	0.0	0.0	2.0	3.1	2.3	2.2	3.3	6.5	1.9	2.3	7.9				
	Mean	920.0	135.0	150.0	1605.0	6.5	1.2	1.3	7.3	1.3	0.0	0.0	1.0	8650.0	1020.0	1025.0	9050.0	2.0	0.0	0.0	2.6	3.1	2.3	2.6	3.6	8.3	2.1	2.9	10.0				
	S.E.	180.0	25.0	50.0	865.0	0.5	0.2	0.3	0.9	0.5	0.0	0.0	1.0	1350.0	60.0	255.0	1850.0	0.5	0.0	0.0	0.6	0.0	0.0	0.4	0.3	1.8	0.2	0.6	2.1				
Impact	I1	1300.0	180.0	270.0	2440.0	8.2	1.5	1.8	5.9	3.4	1.8	1.8	2.4	10000.0	1000.0	1270.0	6440.0	2.9	0.0	0.0	2.7	3.3	1.4	1.4	2.5	12.0	2.3	5.0	10.9				
	I2	1300.0	240.0	250.0	2610.0	7.5	1.8	1.8	6.4	2.6	2.4	1.1	2.3	10000.0	1470.0	1380.0	7510.0	2.7	0.0	0.0	2.8	3.2	2.0	1.8	2.9	11.0	3.1	4.0	11.8				
	I3	1100.0	160.0	170.0	2310.0	6.8	1.4	1.6	6.7	1.4	0.0	0.0	1.1	8900.0	1160.0	1070.0	7090.0	2.3	0.0	0.0	2.2	3.8	2.0	2.2	3.0	9.7	2.7	3.6	9.0				
	I4	1100.0	150.0	170.0	2330.0	6.9	1.3	1.6	6.4	1.3	0.0	0.0	1.2	9400.0	1120.0	1070.0	7190.0	2.2	0.0	0.0	2.1	3.2	2.2	2.3	3.0	9.7	2.6	4.2	9.4				
	I5	1200.0	190.0	180.0	2800.0	6.5	1.6	1.5	7.2	1.5	0.0	0.0	2.4	9900.0	1300.0	1250.0	8710.0	2.3	0.0	0.0	3.1	3.1	2.2	2.2	4.0	9.5	2.8	3.4	12.6				
	I6	1100.0	160.0	210.0	2940.0	6.5	1.4	1.7	7.4	1.5	0.0	0.0	3.4	9200.0	1180.0	1320.0	9060.0	2.2	0.0	0.0	3.5	3.1	2.0	2.5	4.1	9.7	2.6	4.2	16.1				
	S2*	1200.0	180.0	230.0	2460.0	7.4	1.5	1.9	5.8	1.8	2.3	0.0	2.0	10000.0	1290.0	1350.0	6600.0	2.6	0.0	0.0	2.4	3.3	2.3	2.2	2.7	11.0	3.2	4.4	9.8				
	Mean	1185.7	180.0	211.4	2555.7	7.1	1.5	1.7	6.5	1.9	0.9	0.4	2.1	9628.6	1217.1	1244.3	7514.3	2.5	0.0	0.0	2.7	3.3	2.0	2.1	3.2	10.4	2.8	4.1	11.4				
	S.E.	34.0	11.3	15.2	90.5	0.2	0.1	0.1	0.2	0.3	0.4	0.3	0.3	172.8	57.2	48.0	380.9	0.1	0.0	0.0	0.2	0.1	0.1	0.1	0.2	0.4	0.1	0.2	0.9				

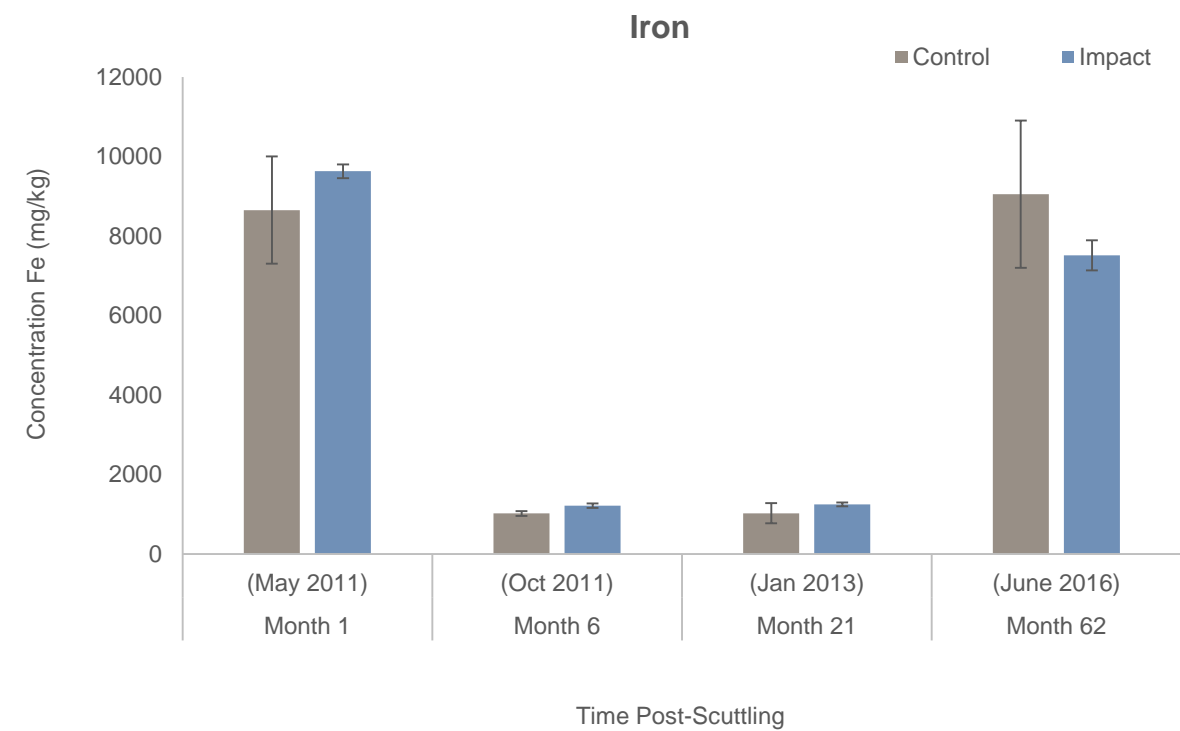
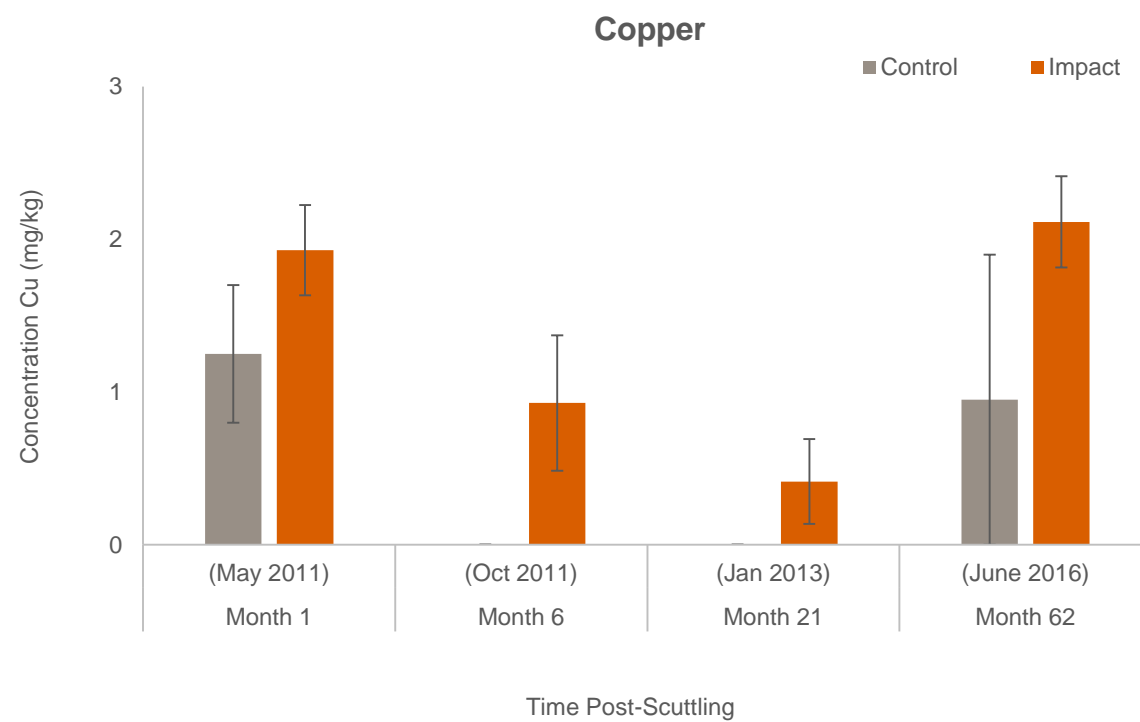
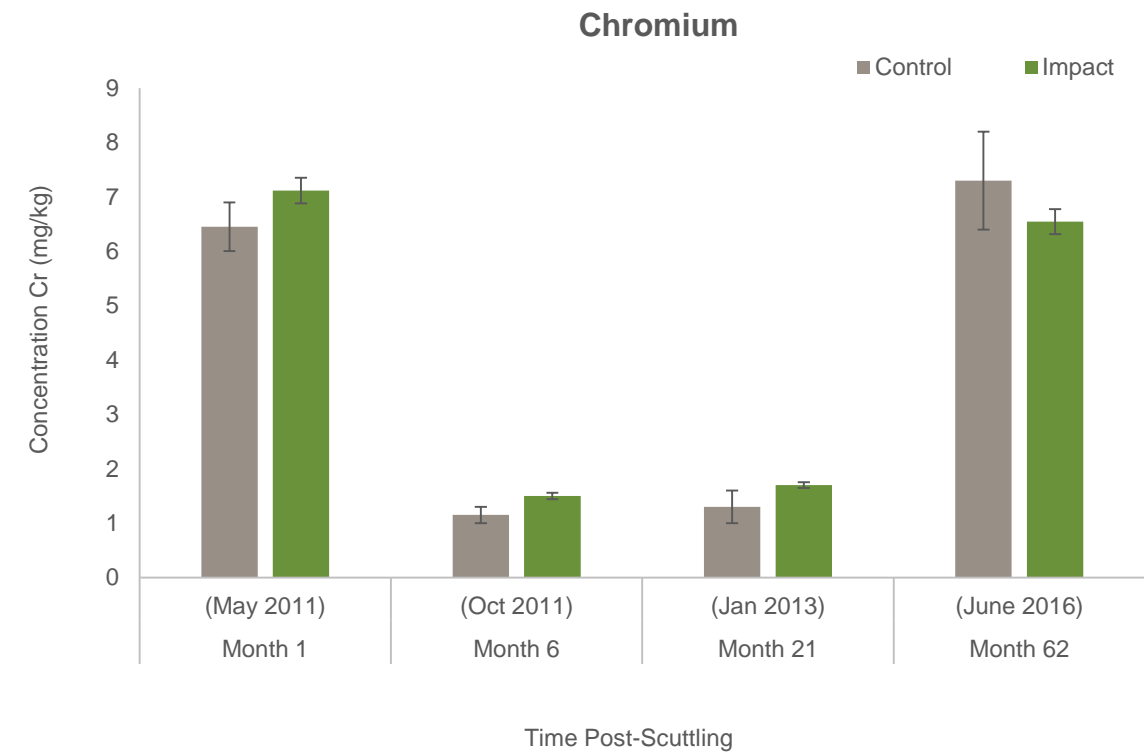
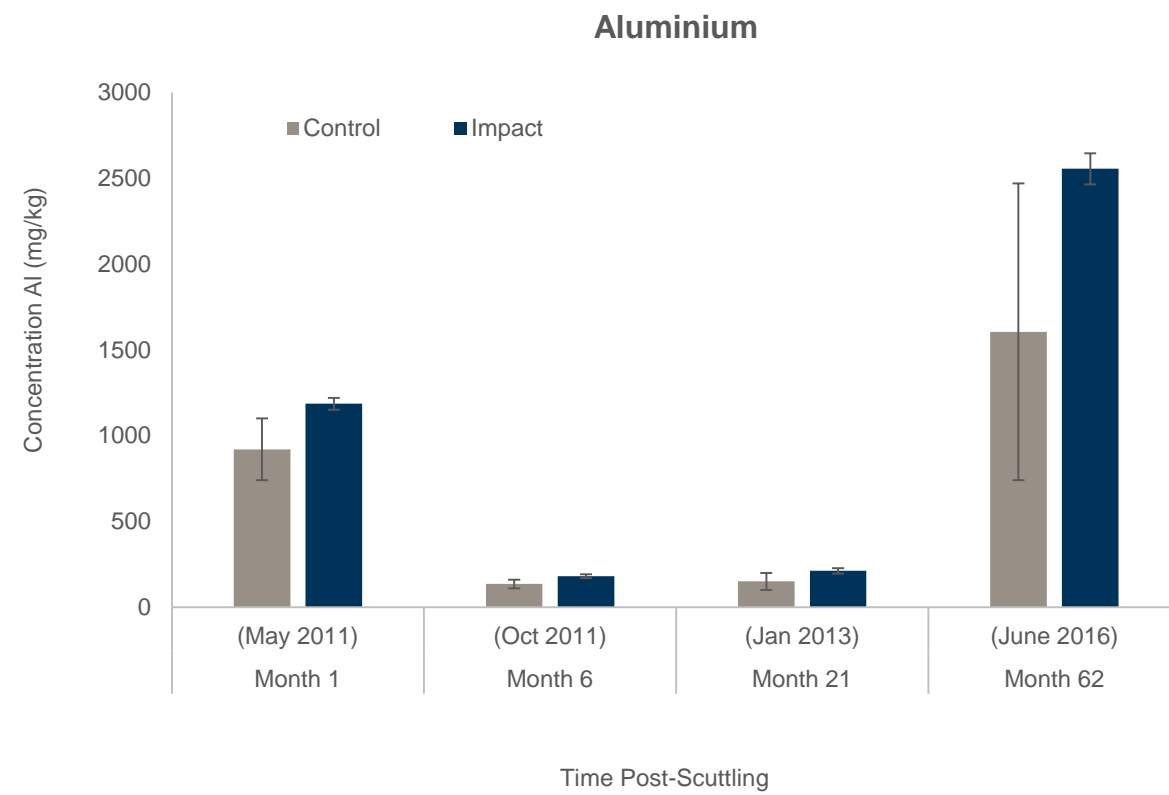


Figure 3. Mean Heavy Metal Concentrations Recorded in Sediment Samples Collected from Monitoring and Control Locations during May 2011 (one month post-scuttling), October 2011 (six months post-scuttling), January 2013 (21 months post-scuttling) and June 2016 (62 months post scuttling)

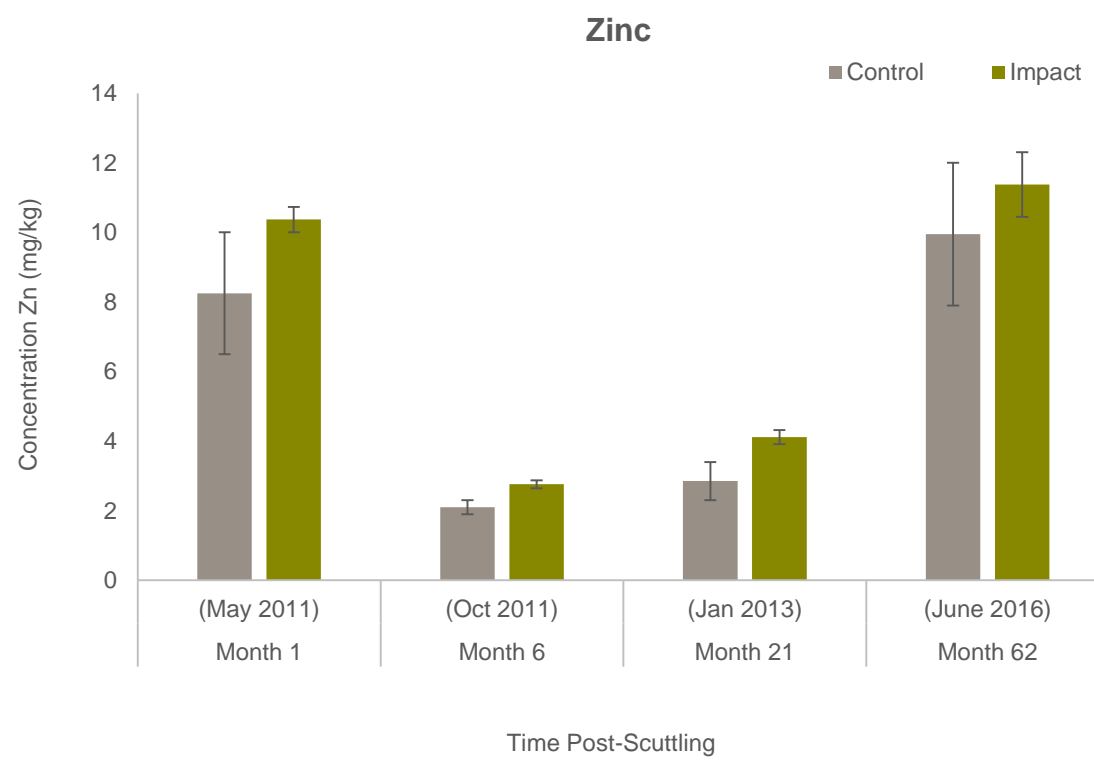
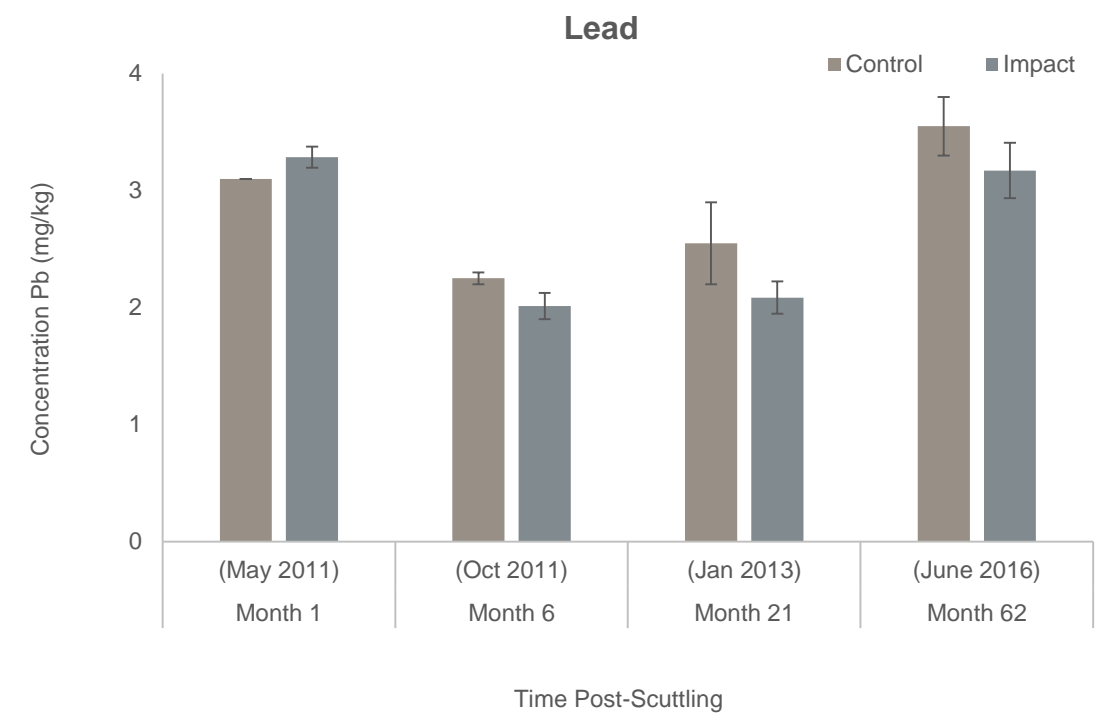
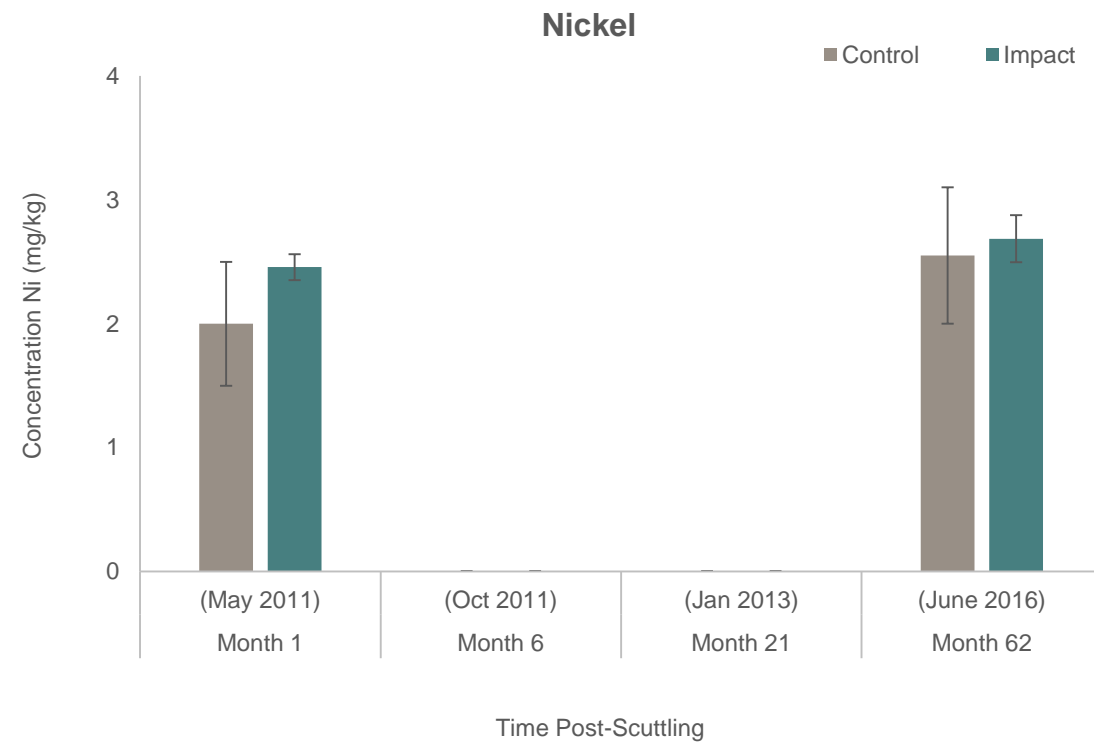


Figure 3. Continued

4 Conclusions

- In general, metal concentrations recorded 62 months post-scuttling (June 2016) were similar to those recorded after only one month post-scuttling (May 2011) and therefore, did not indicate any significant long-term effects as a result of the ship.
- The exception to this was for aluminium, which showed an overall increase in concentrations at impact sites 62 months post-scuttling in comparison with that recorded 1 month post-scuttling. This increase appeared to be greater at the impact location compared to the control location (in June 2016), although this difference was not statistically significant.
- Given the uniformity in particle size distribution (June 2016), this was not considered a factor in the differences in aluminium concentrations between control and impact sites.
- Metal concentrations recorded 6 months post-scuttling (Oct 2011) and 21 months post-scuttling (Jan 2013) were generally notably lower than the levels recorded 1 and 62 months post-scuttling.
- For metals where guidelines are available (chromium, copper, nickel, lead and zinc), concentrations were all well below the ISQG lower trigger values and were not therefore considered to represent a contamination risk to the marine environment.

5 Discussion

It is possible that the apparent increase in concentrations of aluminium observed could be associated with the ship, as aluminium is a component of the superstructure which is likely to corrode over time. Aluminium is also naturally present in the marine environment, often as a result of airborne inputs (Clark 2007). There is, however, very little information in the literature to provide an indication of what broader ‘background’ levels might be in marine sediments of the east coast of Australia and any seasonal fluctuations in natural levels. In the absence of sediment quality guideline values (SQGVs), for aluminium, it is also difficult to understand at what concentration of Al, impacts to marine biota could potentially be expected. Where SQGVs do not exist, a multiple lines of evidence approach may therefore be adopted, for example through the use of other ecological indicators, such as benthic assemblage composition or further bioaccumulation testing. This may help ascertain whether there are biological differences associated with higher concentrations of Al. As guideline trigger values are available for aluminium concentrations in water, this may also be used as a surrogate by testing of sediment pore water.

It is unclear as to what may be driving the general decrease in metal concentrations in samples collected during the surveys 6 months (October 2011) and 21 months (January 2013) post-scuttling. As heavy metals occur naturally in marine sediments and are associated with local and regional geology, it is possible that the elevated levels detected during this study may partly be explained by large-scale oceanographic processes (such as prevailing current, storms etc.) that would be expected to influence the heavy metal content of sediments over timeframes of months to years. It is also possible that higher concentrations, may be related to rainfall events, such as that which occurred in Terrigal and the Sydney area, in the first week of June 2016. Between the 4th and 6th June 2016, 246 mL of rainfall was recorded at Wyong Rainfall Station 061381, approximately 7 km from Terrigal (the closest station for which June 2016 data was available) (BOM 2016). This was just prior to the sediment sampling event on 10 June 2016. It is possible that during this time water from nearby Avoca Lake, which is an intermittently open closed lagoon, was flowing into Bulbararing Bay. Avoca Lake receives stormwater run-off and sewage inputs from the surrounding urban areas, and it is possible that metal contaminants from stormwater run-off or other diffuse inputs had built up in lake water and / sediments. These may have been released into the marine environment following the heavy rainfall and settled into the marine sediment throughout Bulbararing Bay. A study completed by the University of Technology, Sydney for Gosford Council in 1992 for example, detected a mean concentration of copper and zinc in the lake sediment of 4.22 and 11.18 mg/kg, respectively (UTS 1992). These concentrations are greater than, or equivalent to, those sampled in the vicinity of the Ex-HMAS Adelaide in May 2011 and June 2016. It is possible that the heavy rainfall experienced just prior to the current sediment survey, and any associated opening of Avoca Lake, could explain the elevated metal concentrations detected in June 2016. A similar event may also explain the relatively high concentrations detected in May 2011.

Collection and analysis of sediment farther away from the ship (e.g. several kilometres) and over a longer time period would also help determine whether the apparent increase in the concentrations of these metals as associated with the ship or natural processes. In any case, it should be noted that the levels of contaminants detected in this study (for which guideline values are available), were well below the lower ISQG values and are not therefore considered a risk to the marine environment.

6 References

- ANZECC and ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4, Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand, October 2000.
- BOM (2016). Bureau of Meteorology. Climate Statistics. Viewed July 2016.
<http://www.bom.gov.au/climate/dwo/IDCJDW2048.latest.shtml>
- Cardno Ecology Lab (2011). Ex HMAS Adelaide Artificial Reef Sediment Quality Monitoring, Survey 1. Cardno Ecology Lab, St. Leonards, Sydney.
- Cardno Ecology Lab (2013). Ex HMAS Adelaide Artificial Reef Sediment Quality Monitoring, Survey 2. Cardno Ecology Lab, St. Leonards, Sydney.
- NSW Government (2011). Life Before Scuttling – History of the HMAS Adelaide. NSW Government, Queens Square, Sydney.
- University of Technology, Sydney (UTS) (1992). Ecological Assessment of Avoca, Cockrone and Terrigal Lagoons. Prepared for Gosford City Council
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- WorleyParsons (2011). Ex-HMAS Artificial Reef Project – Marine Sediment Quality Survey. Report for the Land and Property Management Authority (LPMA), WorleyParsons, July 2011.

7 Appendices

Appendix 1: Laboratory Results



CERTIFICATE OF ANALYSIS

Work Order	: ES1612869	Page	: 1 of 4
Client	: CARDNO (NSW/ACT)	Laboratory	: Environmental Division Sydney
Contact	: DANIEL PYGAS	Contact	:
Address	: Level 9 The Forum 203 Pacific Highway St Leonards NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 9496 7700	Telephone	: +61-2-8784 8555
Project	: EX HMAS ADELAIDE SEDIMENT SAMPLING 59916176	Date Samples Received	: 14-Jun-2016 16:00
Order number	: ----	Date Analysis Commenced	: 18-Jun-2016
C-O-C number	: ----	Issue Date	: 24-Jun-2016 10:16
Sampler	: DANIEL PYGAS		
Site	: ----		
Quote number	: ----		
No. of samples received	: 9		
No. of samples analysed	: 9		



NATA Accredited Laboratory 825
 Accredited for compliance with
 ISO/IEC 17025.

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Dianne Blane	Laboratory Coordinator (2IC)	Newcastle - Inorganics, Mayfield West, NSW

RIGHT SOLUTIONS | RIGHT PARTNER

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Work Order : ES1612869
Client : CARDNO (NSW/ACT)
Project : EX HMAS ADELAIDE SEDIMENT SAMPLING 59916176



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Ex HMAS Adelaide – Sediment Quality Monitoring Survey 3
 Prepared for Department of Primary Industries – Lands

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 Work Order : ES1612869
 Client : CARDNO (NSW/ACT)
 Project : EX HMAS ADELAIDE SEDIMENT SAMPLING 59916176



Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)				Client sample ID				
Client sampling date / time				I1	I2	I3	I4	I5
[10-Jun-2016]				[10-Jun-2016]	[10-Jun-2016]	[10-Jun-2016]	[10-Jun-2016]	[10-Jun-2016]
Compound	CAS Number	LOR	Unit	ES1612869-001	ES1612869-002	ES1612869-003	ES1612869-004	ES1612869-005
				Result	Result	Result	Result	Result
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1	%	22.5	22.4	19.9	21.7	23.8
EA150: Particle Sizing								
+75µm	----	1	%	99	99	98	99	99
+150µm	----	1	%	74	66	86	88	59
+300µm	----	1	%	6	3	10	11	6
+425µm	----	1	%	<1	<1	3	3	2
+600µm	----	1	%	<1	<1	<1	<1	1
+1180µm	----	1	%	<1	<1	<1	<1	<1
+2.36mm	----	1	%	<1	<1	<1	<1	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	<1	<1	1	<1	<1
Silt (2-60 µm)	----	1	%	1	1	1	1	1
Sand (0.06-2.00 mm)	----	1	%	99	99	98	99	99
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
∅ Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.65	2.67	2.66	2.65	2.65
EG005-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2440	2610	2310	2330	2800
Iron	7439-89-6	50	mg/kg	6440	7510	7090	7190	8710
EG020-SD: Total Metals in Sediments by ICPMS								
Chromium	7440-47-3	1	mg/kg	5.9	6.4	6.7	6.4	7.2
Copper	7440-50-8	1	mg/kg	2.4	2.3	1.1	1.2	2.4
Lead	7439-92-1	1	mg/kg	2.5	2.9	3.0	3.0	4.0
Nickel	7440-02-0	1	mg/kg	2.7	2.8	2.2	2.1	3.1
Zinc	7440-66-6	1	mg/kg	10.9	11.8	9.0	9.4	12.6

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Work Order : ES1612869
Client : CARDNO (NSW/ACT)
Project : EX HMAS ADELAIDE SEDIMENT SAMPLING 59916176



Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)		Client sample ID			I6	S2	S3	S6	----
		Client sampling date / time			[10-Jun-2016]	[10-Jun-2016]	[10-Jun-2016]	[10-Jun-2016]	----
Compound	CAS Number	LOR	Unit	ES1612869-006	ES1612869-007	ES1612869-008	ES1612869-009	----	
				Result	Result	Result	Result	---	
EA055: Moisture Content									
Moisture Content (dried @ 103°C)	----	1	%	23.6	21.4	21.6	21.6	---	
EA150: Particle Sizing									
+75µm	----	1	%	98	99	98	99	---	
+150µm	----	1	%	60	68	71	94	---	
+300µm	----	1	%	7	6	4	17	---	
+425µm	----	1	%	3	1	<1	2	---	
+600µm	----	1	%	1	<1	<1	<1	---	
+1180µm	----	1	%	<1	<1	<1	<1	---	
+2.36mm	----	1	%	<1	<1	<1	<1	---	
+4.75mm	----	1	%	<1	<1	<1	<1	---	
+9.5mm	----	1	%	<1	<1	<1	<1	---	
+19.0mm	----	1	%	<1	<1	<1	<1	---	
+37.5mm	----	1	%	<1	<1	<1	<1	---	
+75.0mm	----	1	%	<1	<1	<1	<1	---	
EA150: Soil Classification based on Particle Size									
Clay (<2 µm)	----	1	%	1	<1	<1	<1	---	
Silt (2-60 µm)	----	1	%	1	1	1	1	---	
Sand (0.06-2.00 mm)	----	1	%	98	99	99	99	---	
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	---	
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	---	
EA152: Soil Particle Density									
ø Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.64	2.67	2.66	2.66	---	
EG005-SD: Total Metals in Sediments by ICP-AES									
Aluminium	7429-90-5	50	mg/kg	2940	2460	2470	740	---	
Iron	7439-89-6	50	mg/kg	9060	6600	10900	7200	---	
EG020-SD: Total Metals in Sediments by ICPMS									
Chromium	7440-47-3	1	mg/kg	7.4	5.8	8.2	6.4	---	
Copper	7440-50-8	1	mg/kg	3.4	2.0	1.9	<1.0	---	
Lead	7439-92-1	1	mg/kg	4.1	2.7	3.8	3.3	---	
Nickel	7440-02-0	1	mg/kg	3.5	2.4	3.1	2.0	---	
Zinc	7440-66-6	1	mg/kg	16.1	9.8	12.0	7.9	---	