ITEM 9. Exploration

Exploration in the TOML tenement area comprises two main phases:

- Historical work and data collected by the pioneer contractors who returned Reserved Areas to the ISA. This work underpins much of the inferred mineral resource estimated in Item 14 and reported previously (Golder Associates, 2013).
- TOML work and data acquired by TOML during two exploration cruises in 2013 and 2015 (called CCZ13 and CCZ15 respectively in this report). This work underpins part of the inferred mineral resource estimated in Item 14 as well as all of the indicated and measured mineral resource estimates.

9.1 Historical Data

Six exploration groups are known to have surveyed areas within the TOML tenement area and collected samples of polymetallic nodules. Much of this work overlapped as it predated the signing of the Law of the Sea. These include the Japanese group (DORD), the South Korean group (KORDI), the Russian Federation group (Yuzhmorgeologiya), the French group (Ifremer), the German group (FIGNR or BGR), and the consortium, Ocean Minerals Company (OMCO). The timing and location (ISA, 2003) of the OMCO sampling is known but the results are not available outside of ISA published contour maps (e.g. Item 7).

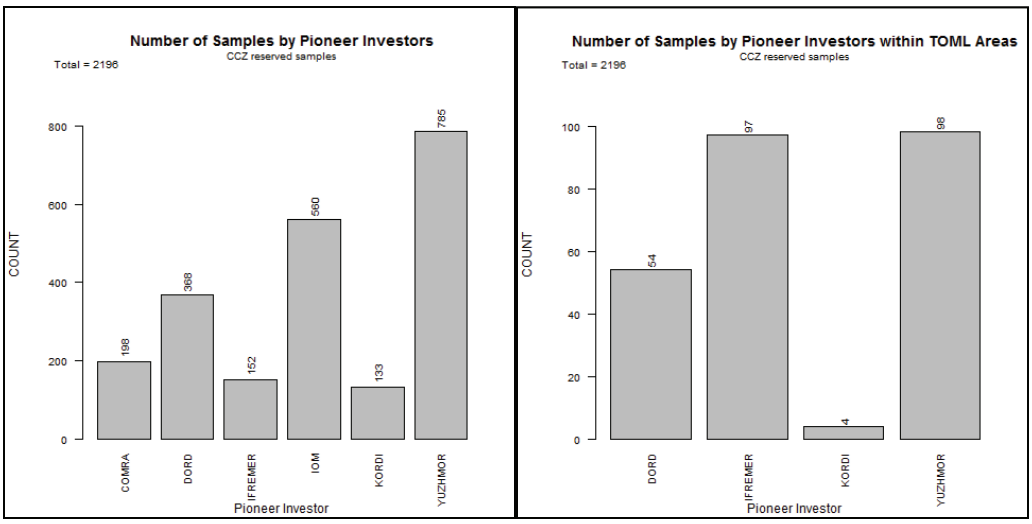
Virtually all the samples in the TOML tenement area were obtained by free fall grab (FFG) samplers, although a few results from box corers (BC) were also included. As detailed in section 7.5.6, nodule abundance (wet kg/m^2) is derived by dividing the weight of recovered nodules by the surface area covered by the open jaws of the sampler or corer (typically 0.25 to 0.5 m^2 but in some cases as much as 1 m^2). Assays were done on dried sample splits by commonly used spectrometric methods (AAS and XRF).

9.1.1 Nodule Sample Data Supplied to TOML

The TOML tenement area was a Reserved Area and as such was sampled by Pioneer Investor or developed nation sponsored contractors (Item 4). These sample data provide the basis of a database held and maintained by the ISA. These data were used initially to define the areas of the TOML application, and subsequently to estimate an inferred mineral resource for the part of the TOML tenement area they covered (Golder Associates, 2013).

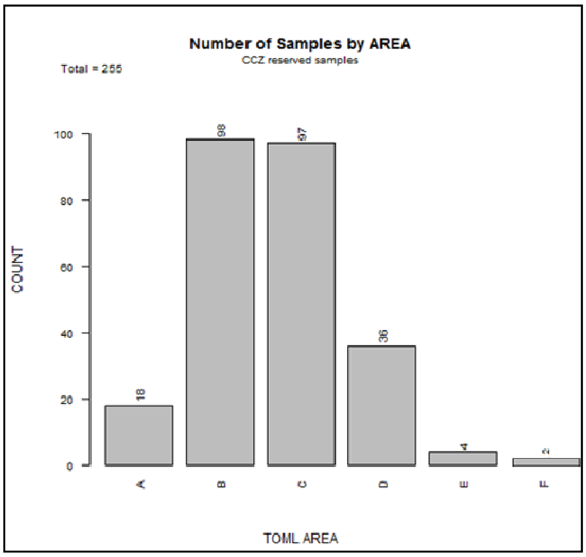
Bar plots showing the total number of samples within the TOML tenement area collected by each Pioneer Investor or developed nation contractor are presented in Figure 9.1 and Figure 9.2. A plan of the sample locations is presented in Figure 9.3. The statistics for the samples that contain both abundance and grade data inside the TOML tenement area are tabulated in Table 9.1 to Table 9.6 and illustrated in Figure 9.3. Samples in the CCZ but outside the TOML tenement area are presented in Table 9.6.

Figure 9.1 Total Number of Samples by Pioneer Contractor.



Pioneer Contractors are sometimes referred to as Pioneer Investors

Figure 9.2 Total Number of Samples by TOML tenement areas.



Note that 8 additional samples were received for Area E from IOM (see Table 9.5).

Table 9.1 Summary of Historical Grab Samples Area A

(ex-DORD)	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	18	18	18	18	18
Minimum	21.46	0.15	0.71	0.46	2.68
Maximum	30.05	0.30	1.47	1.51	17.93
Mean	25.40	0.22	1.14	1.00	10.12
Median	25.50	0.21	1.15	1.02	9.19
Standard Deviation	2.44	0.04	0.24	0.35	5.08
Coefficient of Variation	0.10	0.18	0.21	0.35	0.50

Table 9.2 Summary of Historical Grab Samples Area B

(ex-Yuzhmorgeologiya)	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	88	88	88	88	88
Minimum	10.30	0.02	0.53	0.40	0.03
Maximum	31.20	0.35	1.51	1.40	26.00
Mean	25.40	0.25	1.16	0.94	8.82
Median	26.55	0.25	1.23	1.02	8.09
Standard Deviation	4.19	0.06	0.23	0.26	5.87
Coefficient of Variation	0.16	0.22	0.20	0.27	0.67

Excludes samples that had no nodules.

Table 9.3 Summary of Historical Grab Samples Area C

(ex- Ifremer)	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	78	78	78	78	78
Minimum	22.01	0.14	0.93	0.71	1.35
Maximum	30.90	0.32	1.42	1.44	21.25
Mean	27.91	0.25	1.27	1.15	9.98
Median	28.55	0.25	1.29	1.19	9.17
Standard Deviation	2.13	0.03	0.10	0.15	4.20
Coefficient of Variation	0.08	0.13	0.08	0.13	0.42

Excludes samples that had no nodules.

Table 9.4 Summary of Historical Grab Samples Area D

(ex-DORD)	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	36	36	36	36	36
Minimum	22.79	0.19	1.09	0.79	0.12
Maximum	30.45	0.30	1.44	1.36	16.37
Mean	28.52	0.22	1.31	1.16	7.68
Median	28.76	0.22	1.32	1.17	7.78
Standard Deviation	1.47	0.02	0.08	0.10	4.09
Coefficient of Variation	0.05	0.10	0.06	0.08	0.53

Table 9.5 Summary Historical Grab Samples Area E

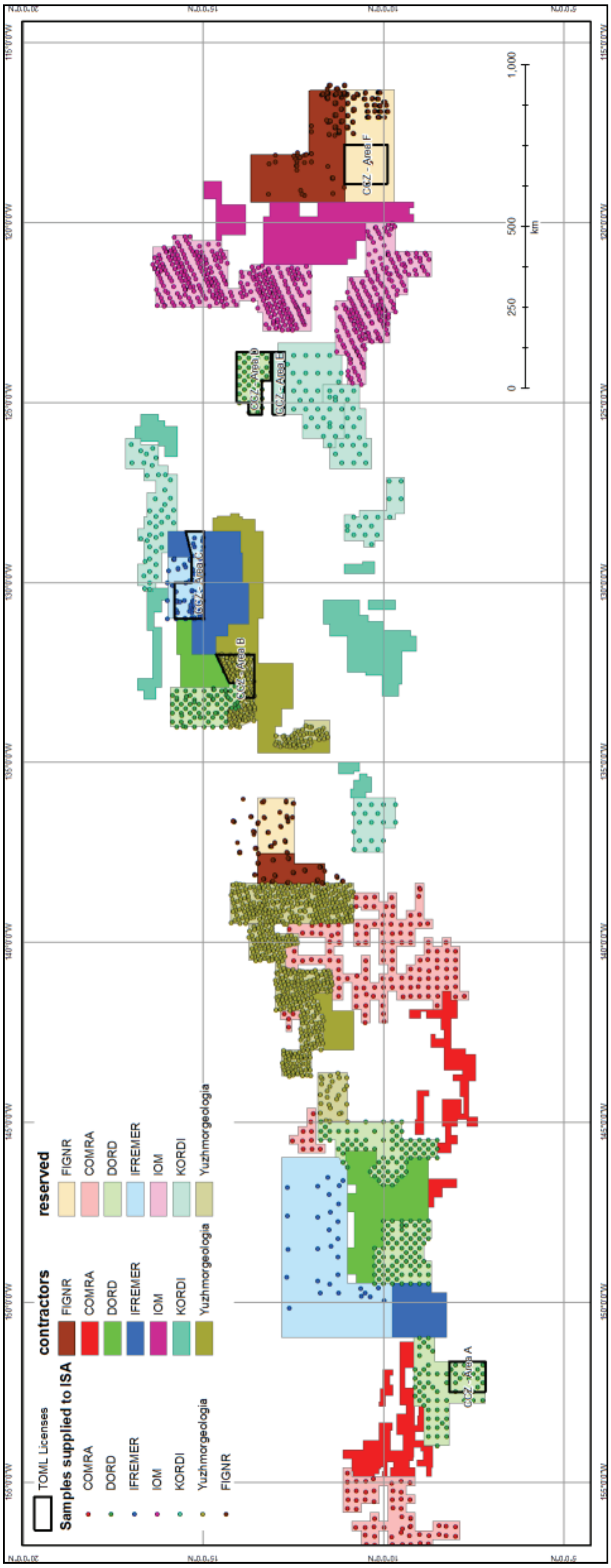
(ex-KORDI, IOM)	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	10	10	10	10	10
Minimum	24.04	0.16	0.96	0.69	1.48
Maximum	31.34	0.27	1.43	1.27	22.90
Mean	27.54	0.21	1.21	1.07	11.34
Median	27.17	0.22	1.21	1.11	9.22
Standard Deviation	2.58	0.04	0.18	0.17	6.82
Coefficient of Variation	0.09	0.18	0.15	0.16	0.60

Table 9.6 Summary of Historical Samples from the Reserved Areas outside the TOML tenement area

	Mn (%)	Co (%)	Ni (%)	Cu (%)	Abundance (wet kg/m^2)
Count	2188	2188	2188	2188	2188
Minimum	4.14	0.05	0.15	0.12	0.01
Maximum	35.62	3.23	1.75	1.62	52.20
Mean	27.47	0.21	1.25	1.04	8.21
Median	28.47	0.21	1.30	1.09	7.10
Standard Deviation	4.06	0.08	0.20	0.24	6.06
Coefficient of Variation	0.15	0.40	0.16	0.24	0.74

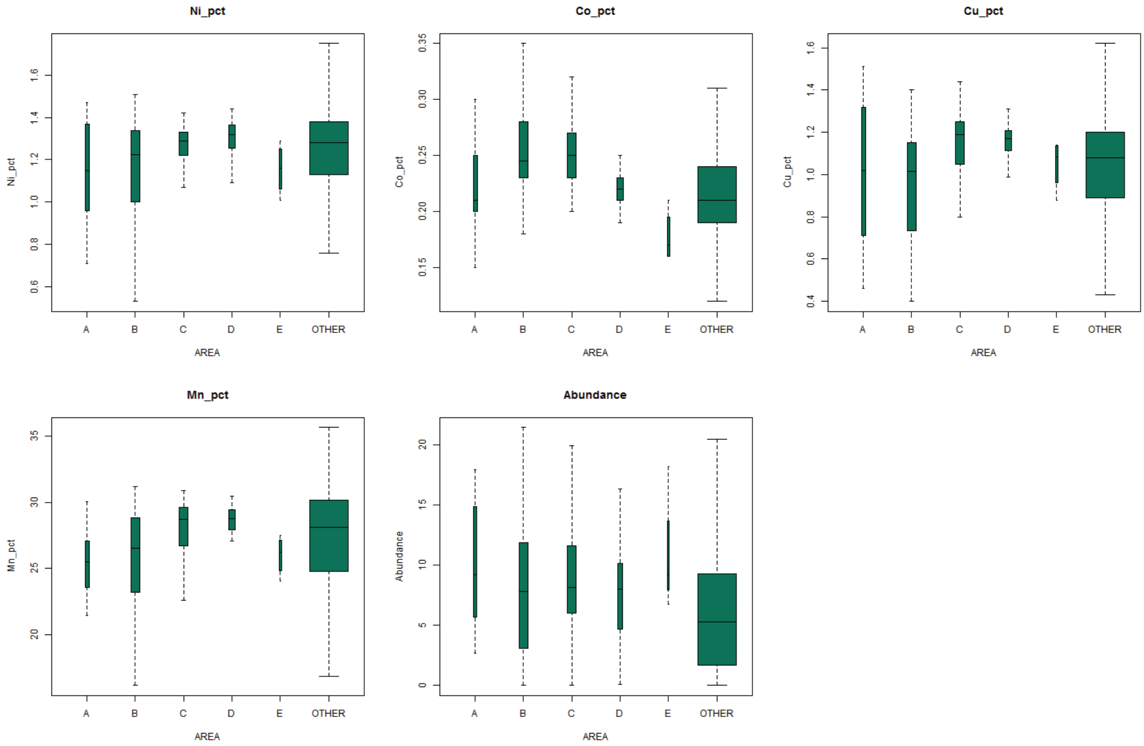
The above tables and Figure 9.4 indicate that all of the TOML tenement areas have similar ranges of grade and abundance to the rest of the CCZ deposit. The coefficients of variation of grades are low compared to most terrestrial mineral resources. Abundance values vary more widely, making abundance estimates the key variable of uncertainty in mineral resource estimation. For the historical data, sample spacing is predominantly wide (10 km to 30 km). However, there are a number of closely spaced samples (500 m to <10 km) but these are insufficient to constrain the short range controls on grade and abundance within the TOML tenement areas. TOML's own sampling (see below) serves to constrain the short range.

Figure 9.3 Samples coloured by Pioneer/Developed Nation Contractor (within the Reserved Areas; ISA, 2012a).



TOML Area	Pioneer/Developed Nation Contractor
A	DORD
B	Yuzhmorgeologiya
C	Ifremer
D	DORD
E	KORDI
F	OMI-BGR/FIGNR

Figure 9.4 Box Plots of historical sample grades within the TOML tenement areas.



Box size represents 1st and 3rd quartiles centred on the median and box width reflects number of samples

Figure 9.5 Box Plots comparing the 6 Pioneer Investor Reserved Area Data Sets across the entire CCZ.

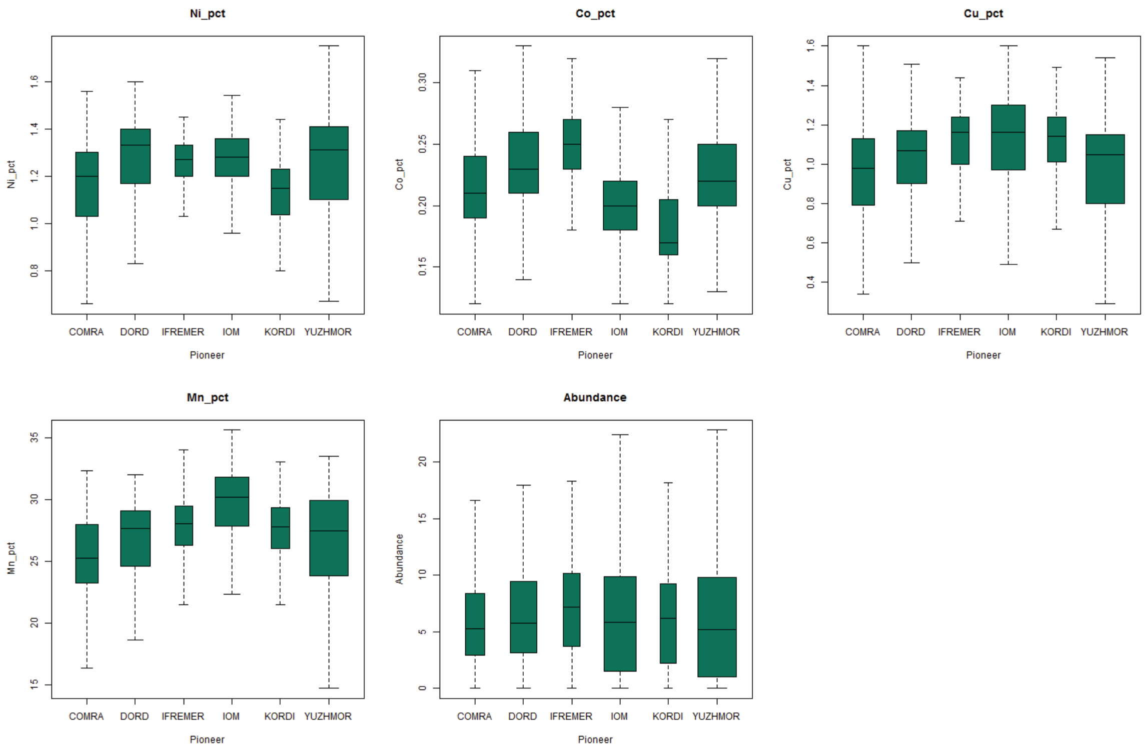
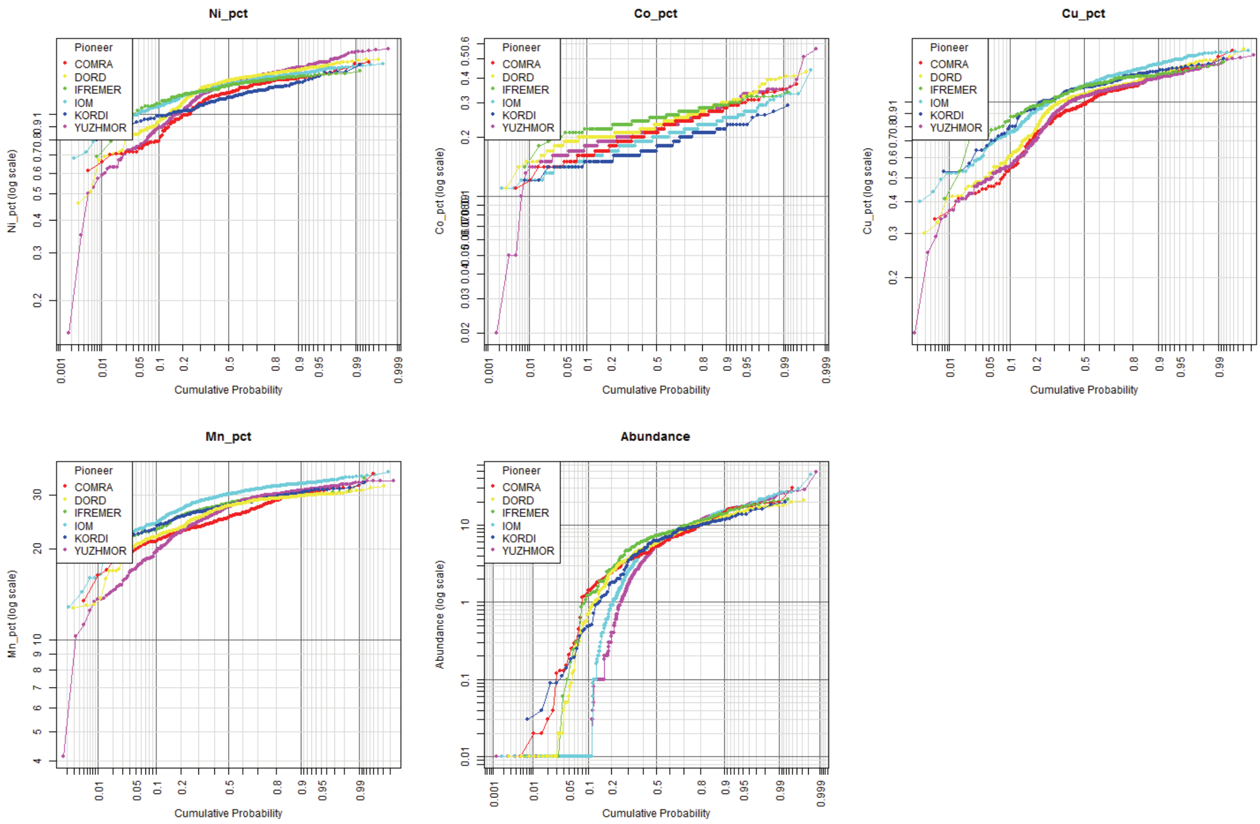


Figure 9.6 Log Probability plots comparing the 6 Pioneer Investor Data Sets.



9.1.2 Historical Sampling Method

Virtually all the historical samples used in the TOML Mineral Resource estimates were obtained by FFG samplers plus a few by BC samplers. Research has shown that free fall grab samplers consistently underestimate the actual abundance (Hennigar, Dick and Foell, 1986), but even today they are the most productive tool available for the assessment of nodule abundance. This is because a number of them can be deployed at any one time from the survey vessel allowing an order of magnitude increase in collection efficiency. I.e. approximately 10 to 20 samples per day for a FFG, versus about three samples per day for a BC that is winched to and from the seafloor.

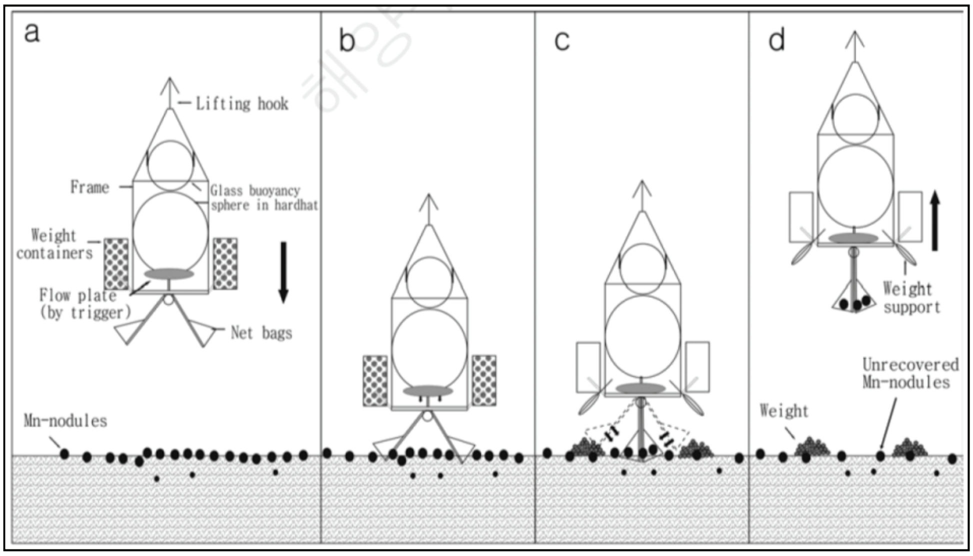
Lee et al. (2008) compared FFG and BC data in some detail. They found a wide range but consistent differences with FFG under-reporting compared to BC (Figure 9.9). They also illustrate why BC results should be much more accurate than FFG results based on mechanical effectiveness (Figure 9.7, Figure 9.8). They then recommend an overall correction factor of 1.4 to convert a FFG abundance to a BC abundance. However, they acknowledge that any simple factor lacks precision. One key issue is the size of the FFG or BC (area covered) versus the nodule diameter. Free fall grab samplers have been demonstrated to underestimate the actual abundance as smaller nodules may escape some grabs during ascent and larger nodules around the edge of the sampler may be knocked out or fall out during the sampling process.

No conversion has been applied to the TOML nodule abundance because:

- Sample collection type is not specified in the historical data (i.e. proportion and identity of BC versus FFG samples is unknown (although most are likely to be FFG).
- The size of collector and nodule sizes is not specified in the historical data.

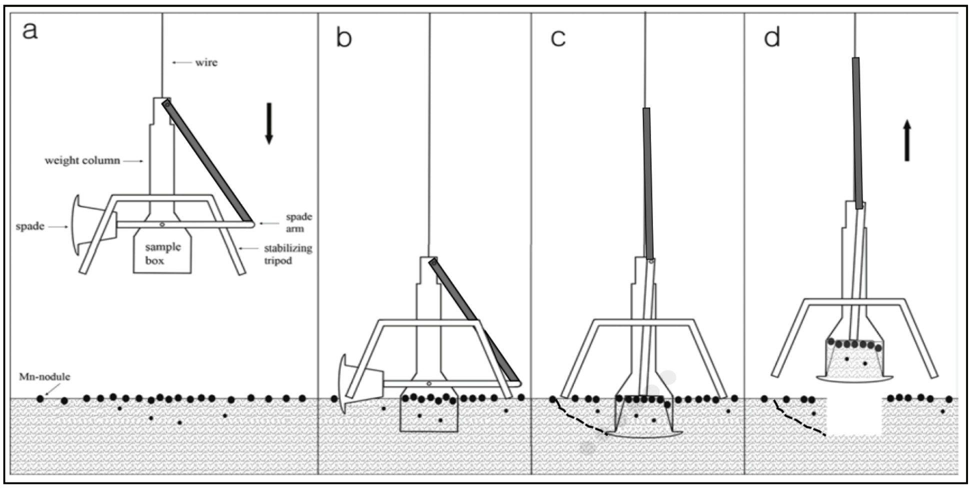
Therefore estimates of nodule abundance based on historical samples are likely to be conservative.

Figure 9.7 Cartoon showing the recovery process of nodules using Free Fall Grab



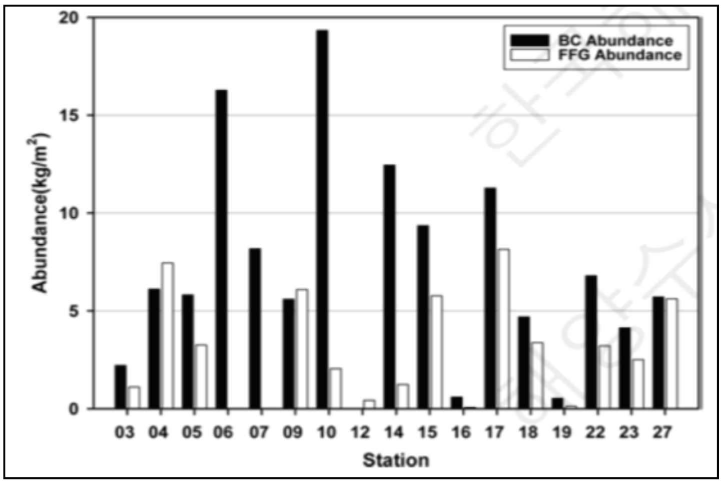
Source: Lee et al., (2008).

Figure 9.8 Cartoon showing the recovery process of nodules using Box Corer



Modified after: Lee et al., (2008).

Figure 9.9 Comparison of returned abundances from BC and FFG at test stations within the KORDI exploration area



Source: Lee et al., (2008).

Metal content in the historical samples was determined by a variety of standard analytical methods, including atomic absorption and X-ray fluorescence. Limited information is available on historical sample preparation and analytical methods (Item 11). The various groups reportedly used polymetallic nodule Certified Reference Materials (e.g. NOD-P-1; Flanagan and Gottfried, 1980) for QAQC, however details of the Certified Reference Materials and analytical results were not included in the dataset supplied by the ISA to TOML and Golder.

9.2 TOML Work Programmes

In 2012, TOML realised the need for two cruises to effectively define a mineral resource of sufficient confidence and size to likely support the building, commissioning and payback of a mining operation.

The first cruise in 2013 utilised the multibeam system of the chartered R/V Mt Mitchell (Figure 9.10) to map the seafloor in Areas B through F, as well as to test equipment and collect sufficient sample to confirm grades and support metallurgical test work.

The second cruise in 2015 used the experienced team and equipment spread on the R/V Yuzhmorgeologiya (Figure 9.10) to sample and image mapped priority areas so that a higher confidence and expanded mineral resource could be estimated, and to collect environmental baseline and geotechnical data.

Figure 9.10 R/V Mt Mitchell (CCZ13) and R/V Yuzhmorgeologiya (CCZ15)

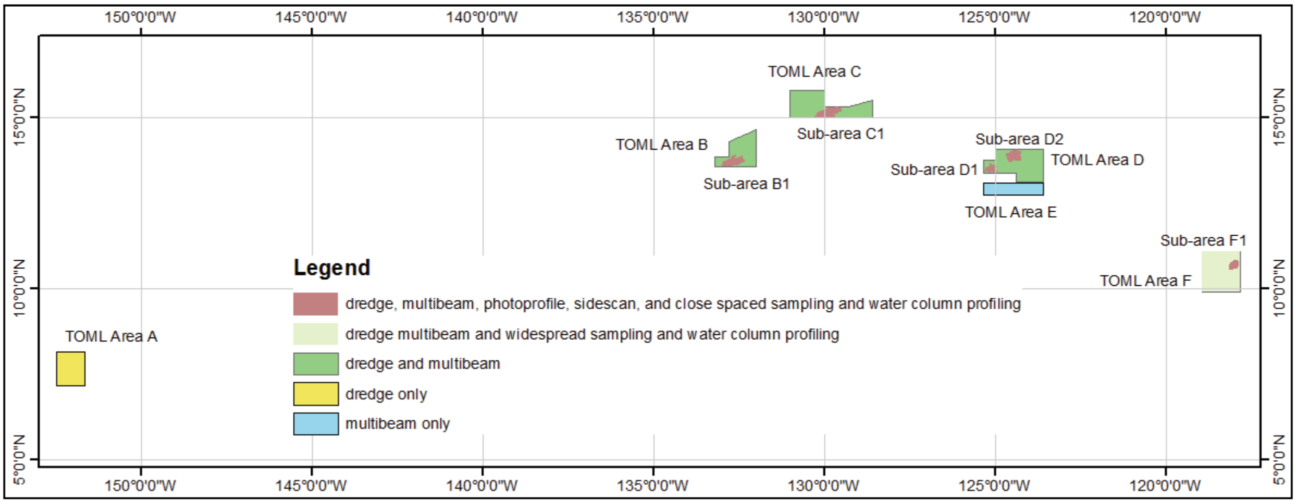
Table 9.7 and Figure 9.11 summarise collected data from each TOML area and sub-area. MBES (12 kHz multibeam echosounding) includes bathymetric and backscatter products and geological geomorphological interpretation. Photo-profile includes still and video products and logging. Dredge sample data includes grade characterisation and some size distribution data. Water column includes temperature, pressure, turbidity and in some cases physical samples and current. Box-core data includes nodule grade and abundance; fauna, and in some cases vane shear and/or sediment characterisation. Deep-tow sonar includes sidescan sonar, sub-bottom profiler and micro survey and altimetry.

Table 9.7 TOML datasets by area and by cruise

	MBES km^2	Photo-profile line km	Dredge #	Water column #	Box-core #	Deep Tow Sonar line km
Area A	–	–	2 CCZ15	–	–	–
Area B	9,966 CCZ13	–	–	–	–	–
Sub-area B1	Included in B	178 CCZ15	1 CCZ13	14 CCZ15	30 CCZ15	88 CCZ15
Area C	15,763 CCZ13	–	–	–	–	–
Sub-area C1	Included in C	231 CCZ15	1 CCZ15	14 CCZ15	16 CCZ15	32 CCZ15
Area D	15,881 CCZ13	92 CCZ15	6 CCZ13	–	–	–
Sub-area D2	Included in D	47 CCZ15	2 CCZ13	26 CCZ15	26 CCZ15	120 CCZ15

	MBES km^2	Photo-profile line km	Dredge #	Water column #	Box-core #	Deep Tow Sonar line km
Sub-area D1	Included in D	39 CCZ15	1 CCZ15	18 CCZ15	16 CCZ15	40 CCZ15
Area E	7,002 CCZ13	–	–	1 CCZ13	–	–
Area F	15,820 CCZ13	–	4 CCZ13	15 CCZ15	15 CCZ15	–
Sub-area F1	Included in F	–	–	9 CCZ15	10 CCZ15	–
Total	64,432	587	17	259	113	280

Figure 9.11 Extent of TOML exploration in the CCZ



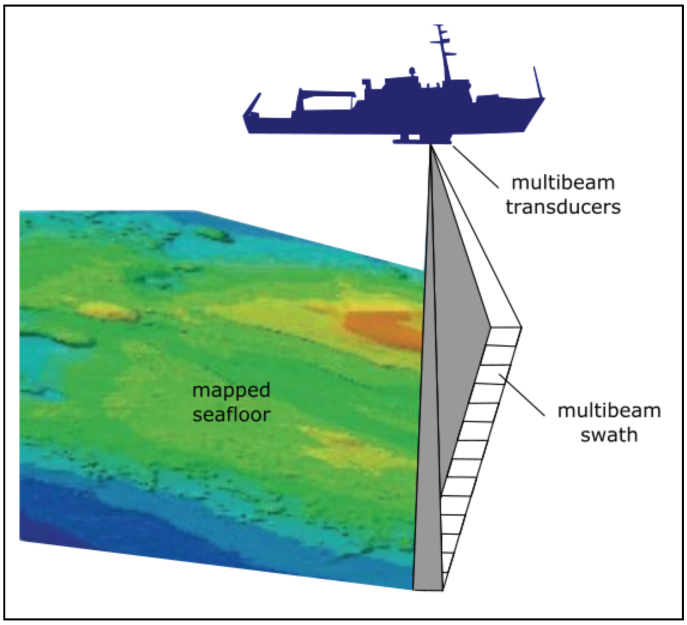
9.3 TOML Sampling Methods

Details of key resource data collection processes and methods are presented here.

9.3.1 Multibeam Bathymetry

Multibeam echo sounding is used to determine the depth of water (bathymetry) and the acoustic reflectance (backscatter) of the seabed. It operates by transmitting a focused acoustic pulse (Figure 9.12) from a specially designed transducer across a swath across the vessel track. These pulses return as a set of receive beams that are weaker and narrower and whose arrive time varies depending on speed and distance. Thus position and depth can be measured and seafloor hardness can be qualitatively assessed.

Figure 9.12 MBES operations schematic



During the CCZ13 cruise the R/V Mt Mitchell operated a hull mounted Kongsberg EM120 MBES over areas B through F. This equipment operates at 12 kHz and is capable of operation up to 11,000 m water depth. It has better than 5 m vertical resolution and ~60 m horizontal resolution for bathymetry and ~ 30 m for backscatter at water depths between 4,500 - 6,000 m. It has a maximum swath width of 6 times the water depth but the effective swath width varies from 2 to 6 times the water depth depending on the depth, sea state and heading.

The only pre-existing bathymetric data over the TOML tenement areas (excluding occasional widely spaced transit lines collected by research vessels) was the Sandwell and Smith based, satellite bathymetry (BODC, 2014). It is still the only data available for TOML Area A. This bathymetry is calculated using mean sea levels to estimate depth to seafloor, and is good for a resolution of 30 arc seconds (within the TOML areas this roughly equates to 900 m). In a general sense, this data is usually accurate to within a hundred metres vertically, but it lacks the definition necessary to define the smaller seamounts, ridges and smaller bathymetric features. No publicly available backscatter or seafloor reflectance data exists for these survey areas. As a result, conducting these multibeam surveys provides TOML with a significant improvement in the vertical and horizontal resolution of the bathymetry, and with unprecedented intensity definition of the backscatter, resulting in visibly crisper, and much more interpretable imagery.

CTD (conductivity-temperature-depth) soundings were performed at each of the survey areas in 2013. The primary reason for this is that the multibeam system requires an accurate full water column sound velocity profile with which to perform real time beam steering and location calculations.

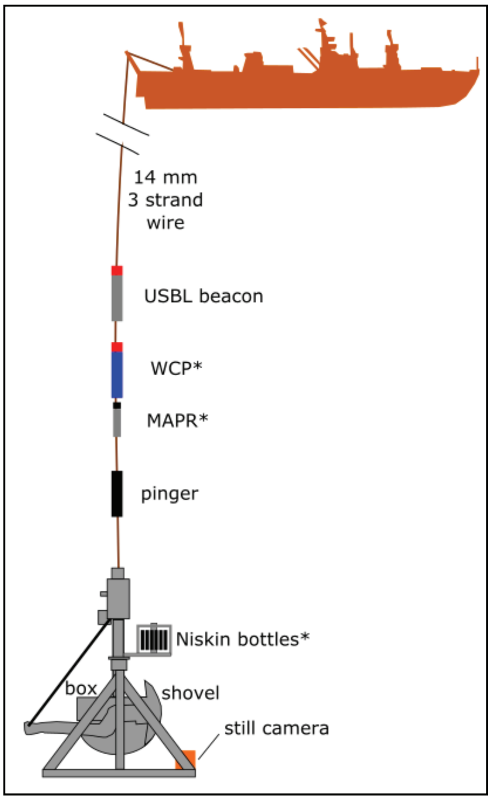
9.3.2 Box-coring

Box-coring was undertaken in 2015 to collect samples for mineral resource estimation, to collect biological samples for environmental base-line measurement and to collect geotechnical data. Box-core operations adhered to the following:

- Deployment and recovery off the stern of the vessl using three strand wire and the vessel's starboard hydrographic sample winch (Figure 9.13)
- The vessel maintained minimum forward speed, typically 0.3 to 0.7 knots into result (combination of surface wind and waves)
- The box-core's progress and status (fired or not) was tracked using a signal from a 12 kHz pinger
- Landing points were within 500 m of the planned grid co-ordinates (as per Dive Plans) with the following pre-conditions:
  - Landing points avoid steeper areas (>10° slope) based on pre-existing multi-beam bathymetry

— The hydrographic surveyors guiding the landing never sight the backscatter product of the existing multi-beam coverage (to eliminate chance of sighting bias)
— USBL navigation provides location to within +-15 m.

Figure 9.13 Box-corer Deployment Schematic



9.3.3 Box-coring Overview

Box-corers have been used in the CCZ since the 1970s. As they collect a seabed sample effectively intact (Figure 9.8), they are seen by most workers as the best possible sampling device to estimate the nodule abundance in any given area. As such, the box-core samples were the most important contributor to the CCZ15 cruise results and by extension, to an independently validated, mineral resource estimate.

Box-corers come in different sizes: typically 0.1 m^2 or 0.25 m^2 (plan area of sample box or tube), but box-corers of 0.75 m^2 and 1 m^2 have also been used.

Smaller box-corers are good for micro-biological sampling of the epibenthic zone and are adequate for the estimation of abundant nodule resources, especially those involving smaller nodules. For accurate estimation of the abundance of larger nodules, especially in lower quantities, larger box-corers are more accurate.

The largest box-corers used in the CCZ were 1 m^2 (Afernod’s Sympas system and one built by the OMCO consortium), but by all accounts, these were very large and difficult to handle. Kennecott built a 0.75 m^2 corer and used it extensively, deeming it to be an effective compromise (Felix, 1980).

9.3.4 Box-corer Equipment

Two types of box-corers were used during the TOML CCZ15 cruise:

- 0.75 m^2 box-corer manufactured by KC Denmark (80.740 code) and supplied by Nautilus Minerals (Figure 9.15). For part of the cruise, the KC box-corer included a carrousel of 12 small volume (300 ml) Niskin bottles for water sampling. Each side of the box has an internal width of just below 87 cm (there are minor variances of 1 - 2 mm with the corner welds), so the true area of 7569 cm^2 is used for the abundance estimation.
- 0.25 m^2 box-corer manufactured by YMG (Figure 9.16) based on a USNEL/Scripps design from the 1970s.

Figure 9.14 Details and operations with the KC box-corer

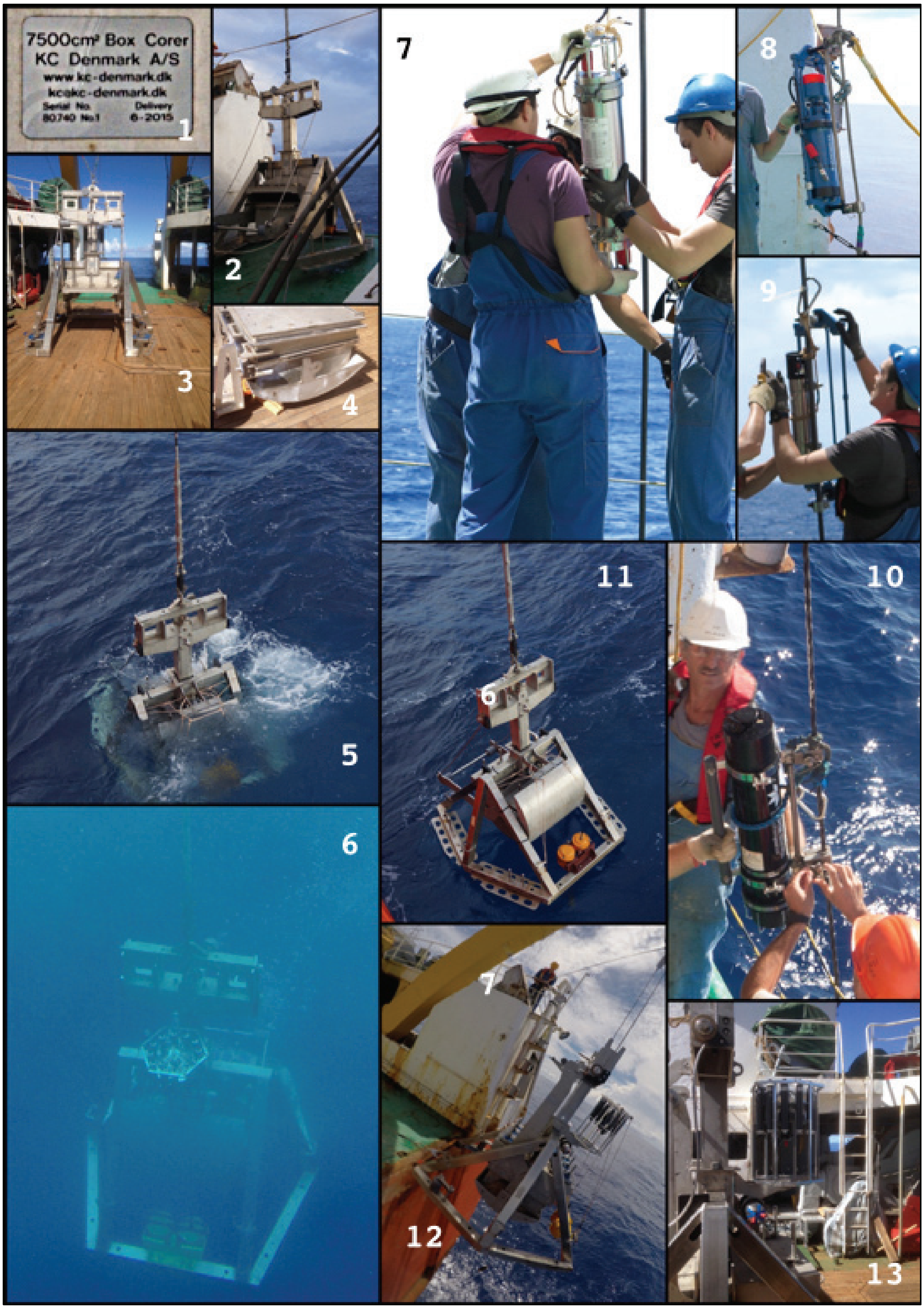
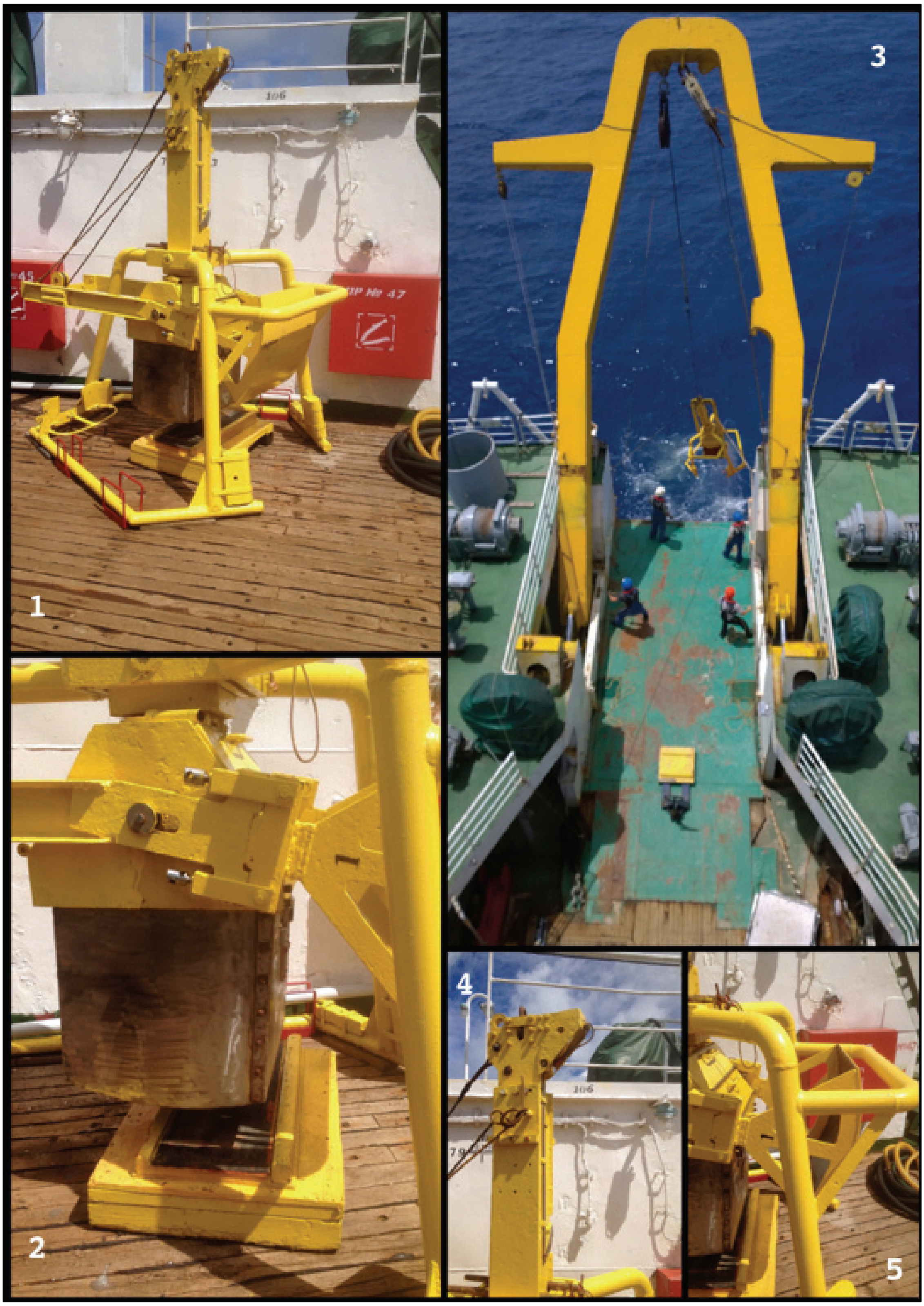


Figure 9.15 Details and recovery of the YMG box-corer



9.3.5 Nodule sampling

Logging was completed manually by the Lead Scientist on shift. The manual logs were scanned and then transposed into MS Excel.

All weights were taken using a Wedderburn Marine motion compensated scale (WM42; Serial number #3380724) that was checked and calibrated in Brisbane, Australia, before shipping to the vessel. The scale has a 40 cm x 40 cm plate with vessel motion recorded and corrected electronically. Scales are claimed to be accurate to 60 kg +/- 50 g, which was as observed during the cruise. The scales were checked using 12 x 1.5 l or 12 x 2 l water bottles and recorded weights were consistent with the mass of water plus packaging.

Upon arrival on deck, the nodules were photographed in situ, removed from the box and weighed three times:

- 1st time with mud still attached (preliminary weight) to enable biological analysis
- 2nd time after washing in filtered salt water (washed weight)
- 3rd time several days later and after exposure to 30-90 minutes in air conditioning and removal of ponded or sweated free water (aired weight).

Note that at each stage of handling, despite due care, some attrition of the nodules occurred with loss of a small (generally <1%) of fine material (dust to sand sized). The bulk of this loss occurred at the washing stage, but it was noticeable at the aired stage as well. The rate of attrition varied by nodule type (rough nodules broke up more) and by area (the rough and smooth rough nodules in the southern part of Area F were especially soft).

The difference between the washed and other weights is illustrated below in Figure 9.17. There is almost no difference between the washed and aired weights (average for all samples over 1 kg is -0.87%; in Area F it is -1.86%), with the cause of the minor differences debatable (moisture or attrition).

Figure 9.16 Preliminary vs. washed vs. aired box-core nodule sample weights (kg)

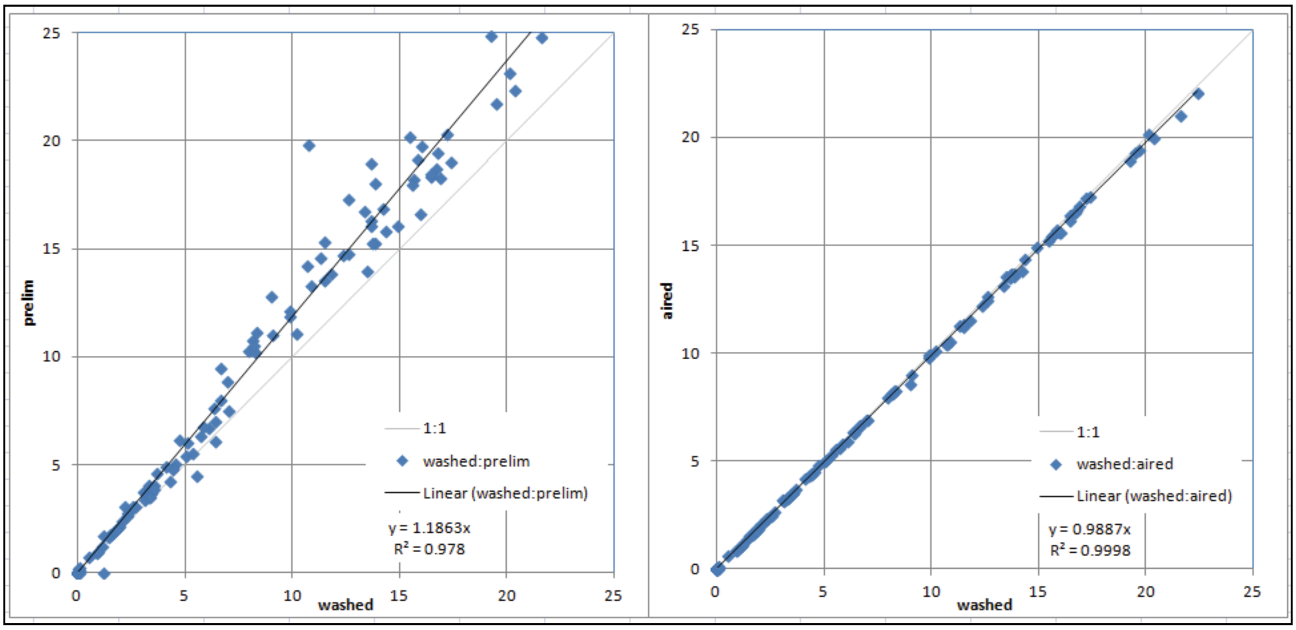
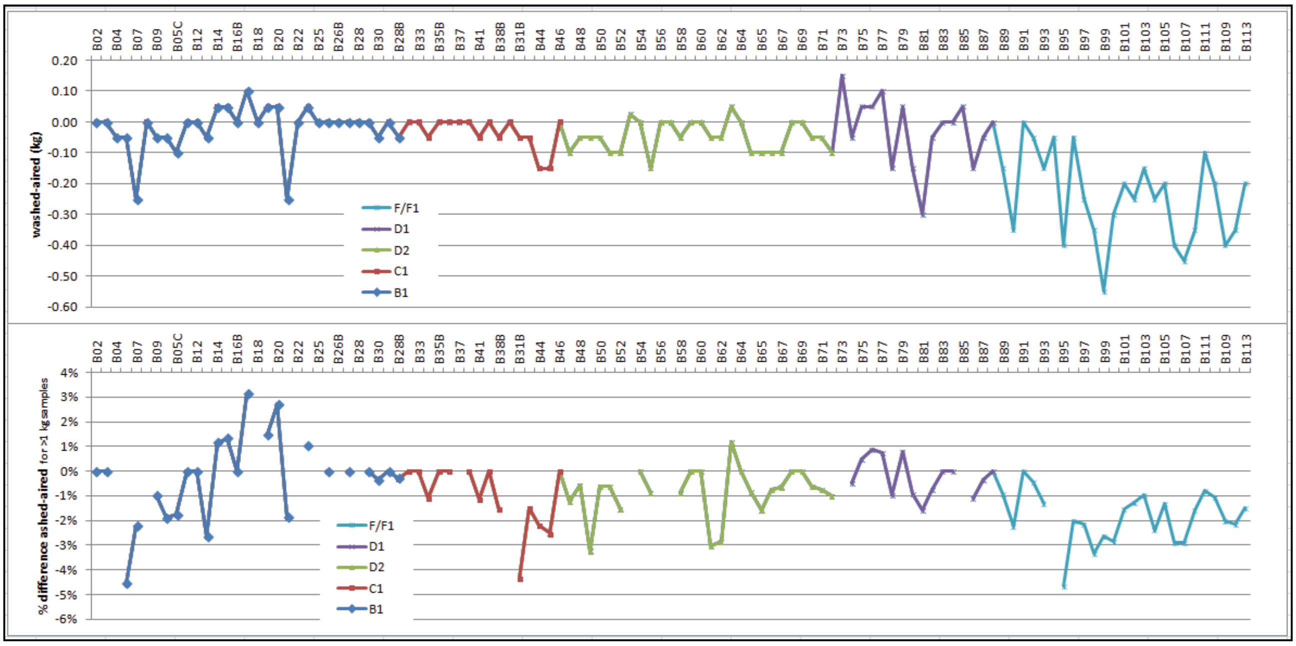


Figure 9.17 Differences in washed vs. aired box-core nodule sample weights by area



Handling of nodules was at all times supervised by the Chief or Lead Scientists, who were also the only people permitted to weigh the nodules, record the weights and seal bags and pails for transport. Nodule sampling was managed as follows (refer Figure 9.18, Plates 1 to 24):

- From the box, nodules were removed to the weighing station (in the geology laboratory or adjacent to the box-core landing spot on the back deck; (Plates 8 &13)
- Here, preliminary weight was taken and recorded, the nodules were washed, firstly the selection with observed fauna, then the rest of the nodules
- Then the washed weight was taken and recorded (Plate 14)
- Then the nodules were carried to the geology laboratory where they were arranged and photographed by a designated scientist before temporary storage in sealed plastic bags in a designated area
- Then at the conclusion of sampling of an area (1-7 days after collection), the samples were laid out about 6-20 at a time for airing (Plates 21 & 22)
- After 30 to 90 minutes of airing, reference and duplicate samples were selected, re-packed weighed again, sealed in plastic bags security tagged with tamper-proof tags or tape and then photographed (Plates 19 & 20)
- Then the nodules were packed into specially marked paint pails with tamper-proof tape (Plate 23).
- Duplicates were collected from roughly one in ten samples. Subsamples were taken using cone and quartering.
- Pails were then transported (escorted by Chief or Lead Scientist) to a refrigerated container (reefer) on deck for transport to Brisbane, Australia, where the main assay laboratory is located (Plate 24).
- Reference samples were placed in specially marked and labelled pails for airfreight to Brisbane, Australia (in case of loss of the reefer in transit). These samples are for general reference purposes, but also serve as backup for chemical analysis. These samples were not sealed with security tags or tamper-proof tape.
- Duplicate samples were placed in specially marked containers and labelled for air-freight to Jacobs University, Bremen, Germany, where the check laboratory is located. These samples and all container pails were sealed with tamper-proof tape.

Figure 9.18 Details and operations regarding sample processing

9.3.6 Buried Nodules

In most samples, there were no buried (i.e. >10cm) nodules although some were occasionally entrained by the sides of the box or the shovel. If present, buried nodules were separated at the point of collection from the box and were washed, weighed, and packed separately. Entrained nodules were sampled for reference purposes only and were not weighed.

9.3.7 Vane Shear Readings

Vane shear was measured in all box-cores that returned with undisturbed sediment. A 33 mm vane on a calibrated hand held shear vane device was used. Measurement location and readings were recorded on the Box-core Sample Log Sheet then transferred to a spreadsheet.

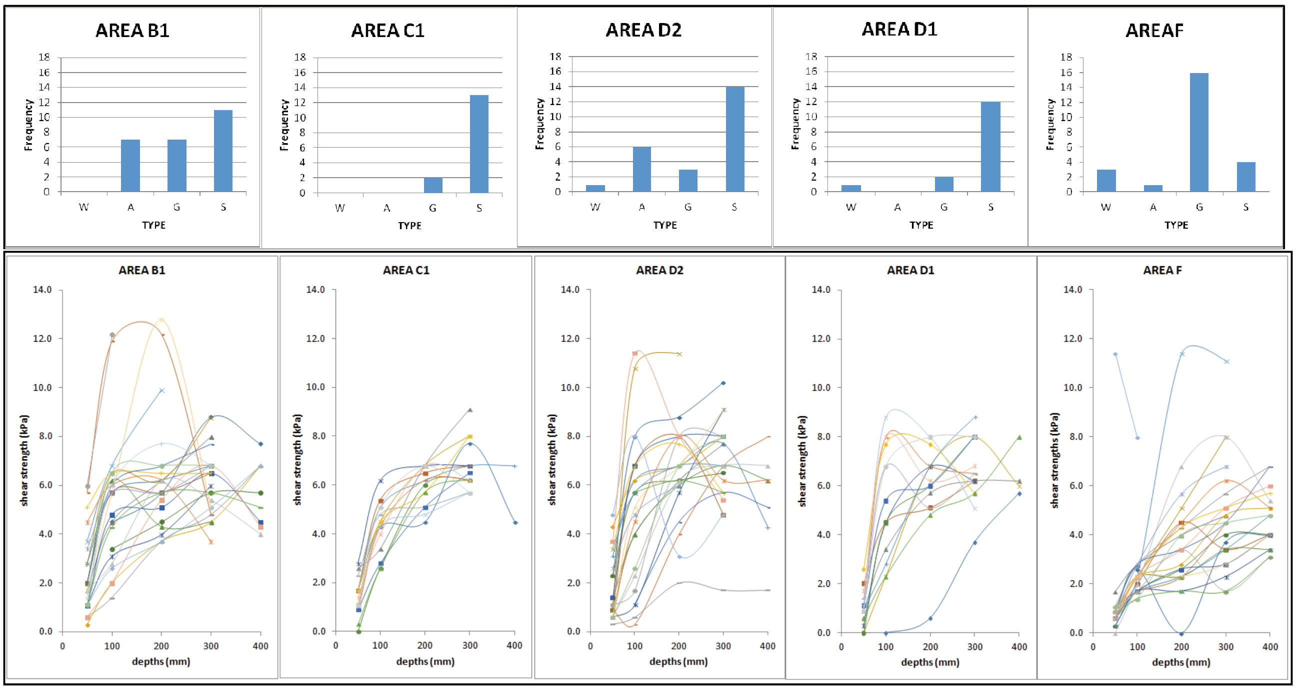
Vane shear was classified into one of four classes:

- W is mostly weak from top to base
- A is all stiff from top to base
- G is soft at the top with gradual stiffening with depth
- S is soft at the top with more sudden stiffening with depth.

Data were also reviewed by box and the most coherent reading selected. Averaging of readings was not undertaken as some measurements were taken in disturbed sediment, especially near the base. The most coherent readings were generally taken in the centre of the box.

Summary results are included in the maps further below, but the classes vary by area as shown in Figure 9.19.

Figure 9.19 Summary vane shear results from TOML CCZ15 study areas



These data shows clear differences in the uppermost part of the sediment between areas, with:

- Area C1 showing consistently suddenly stiffening ground conditions (mostly class S);
- Area D1 showing a slightly wider range to C1 including some more rapidly stiffening situations (mostly class S);
- Areas B1 and D2 have a wider range of conditions and both areas have occurrences of sediment drift (Nnoo);
- Area F (and F1) has a universally weak upper layer then generally and gradually stiffens (mostly class G).

9.3.8 Biological-Sediment sampling

Biological-sediment base-line samples were collected from the majority of box-core samples. These samples were collected in accordance with ISA Technical Study: No.10 “Environmental Management Needs for Exploration and Exploitation of Deep Sea Minerals”. If TOML is to proceed to trial mining/full scale mining, these samples will play a key role in the environmental impact assessment of the proposed mine site(s).

Samples were collected to obtain an understanding of the in-fauna and epi-benthic community composition and sediment characterisation within the TOML tenement areas. A variety of sample types were collected from each box-core, which were fixed and preserved separately for morphological and molecular taxonomy.

Sample types collected and planned analysis:

- Overlying water fauna
- Megafauna (animals greater than 2 cm)
- Nodule fauna
- Micro-fauna (animals smaller than 32 μm)
- Meio-fauna (animals greater than 32 μm and less than 250 μm)
- Macro-fauna (animals greater than 250 μm and less than 2 cm)
- Sediment chemistry
- Particle size distribution
- Special core samples. Sample type collected occasionally to capture unusual sediment characteristics of interest in their original sediment layers.

Collection method, fixing and preservation are illustrated in Figure 9.20 to Figure 9.24. Biological-sediment samples were only collected if the box-core sample was in relatively good condition. If the box-core sample was damaged during collection, or recovery resulting in the mixing of sediment layers, most sample types were not collected. Biological-sediment samples were collected in conjunction with nodule samples. However, care was taken to minimise the mixing of sediment layers during the extraction of nodules.

Between sampling events, all sampling equipment was washed thoroughly using 25 μm filtered seawater to prevent contamination of samples. Sterilised Nalgene sample containers and Whirl-Pak sample bags were used to collect samples. During the collection of sediment chemistry samples, no equipment containing metal was used in order to prevent cross-contamination due abrasion and to trace level analyses.

The following are the essential operations undertaken to collect all samples types listed above. Figure 9.18 displays the order of sample collection and processing:

- Upon retrieval of the box-core to deck and delivery of the box-core samples to science team, overlying water was siphoned off into clean pails using plastic tubing and large pipettes. The water was then poured through a 32 μm sieve and the contents collected and fixed/preserved in 99% ethanol. (Figure 9.18 – Plates 5 & 6)
- Visible mega-fauna were collected from the surface of the sample using forceps, placed in a sample container and preserved. After preliminary weighing of the nodules, selected nodules were washed over a sieve (32 μm) and the contents of the sieve collected and fixed/preserved in 6% formalin or 99% ethanol. Large mega-fauna attached to the nodules were photographed before being removed from the nodule
- The required amount of 5 cm and 10 cm PVC cores were pushed into a box-core sample to a depth of over 20 cm. Rubber bungs were then inserted into the cores (Figure 9.18 – Plates 10 & 11)
- Residue samples were collected using heavy-duty geological sample bags (Figure 9.18, Plate 12),
- PVC cores were extracted from the box-core and placed upright in pails to prevent mixing of layers. Cores were washed to prevent contamination during processing
- PVC cores were analysed either for fauna type or for sediment characterisation, using horizon measurers and core cutter (Figure 9.18 – Plates 15, 16, 17 & 18):
- Micro-fauna (2 x 5 cm diameter cores) – 0-2 cm, 2-5 cm and 5-10 cm horizons were extracted, placed in the appropriate Nalgene sample container and fixed/preserved in 99% ethanol

- Meio-fauna (4 x 10 cm diameter cores) – 0-2 cm, 2-5 cm and 5-10 cm horizons were extracted, placed in the appropriate Nalgene sample container and fixed/preserved in 4% formalin or 99% ethanol
- Macro-fauna (4 x 10 cm diameter cores) – 0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm horizons were extracted and sieved (250 µm). The contents of the sieve placed in the appropriate Nalgene sample container and fixed/preserved in 6% formalin or 99% ethanol
- Sediment chemistry – 0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm horizons were extracted and placed in sterilised Whirl-Pak sample bags
- Particle size distribution – 0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm horizons were extracted and placed in sterilised Whirl-Pak sample bags
- Duplicate samples – were collected
- All samples collected were labelled using the q-Core database, following a pre-determined sample numbering system
- After fixing/preservation, all samples were packed into pails and stored in a refrigerated container kept at 2-4°C (Figure 9.18– Plate 24)
- Samples fixed in 4% and 6% formalin were transferred to buffered 99% ethanol after approximately two weeks for long-term storage and preservation.

The bulk of the samples collected were shipped to Nautilus Minerals in Brisbane, Australia. A selection of overlying fauna, nodule fauna, meio-fauna, macro-fauna and mega-fauna have been shipped to YMG, Gelendzhik, Russia for expert morphological taxonomic identification. Sediment chemistry and particle size distribution samples were sent to SGS, Cairns for analysis. The bulk of the fauna samples will be stored until they can be analysed in accordance with a yet to be scoped environmental impact statement project.

Figure 9.20 Sample Plan – Overlying fauna and nodule

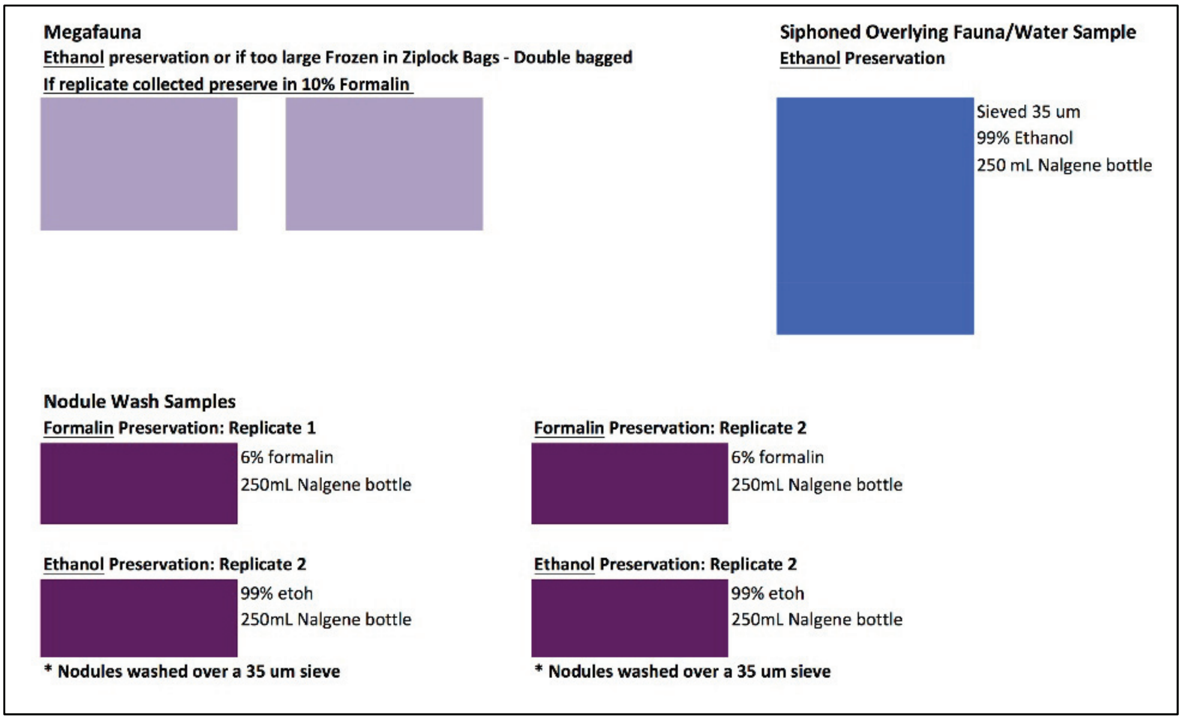


Figure 9.21 Sample Plan – Micro-fauna and box-core layout

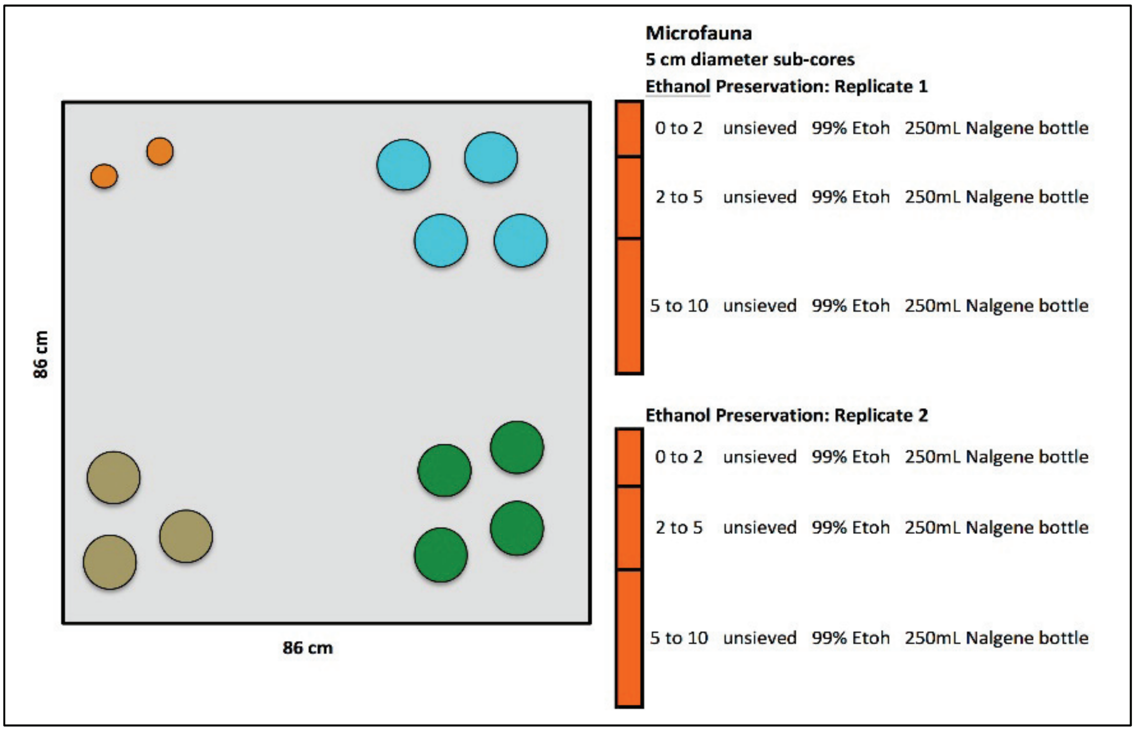


Figure 9.22 Sample Plan – Meio-fauna

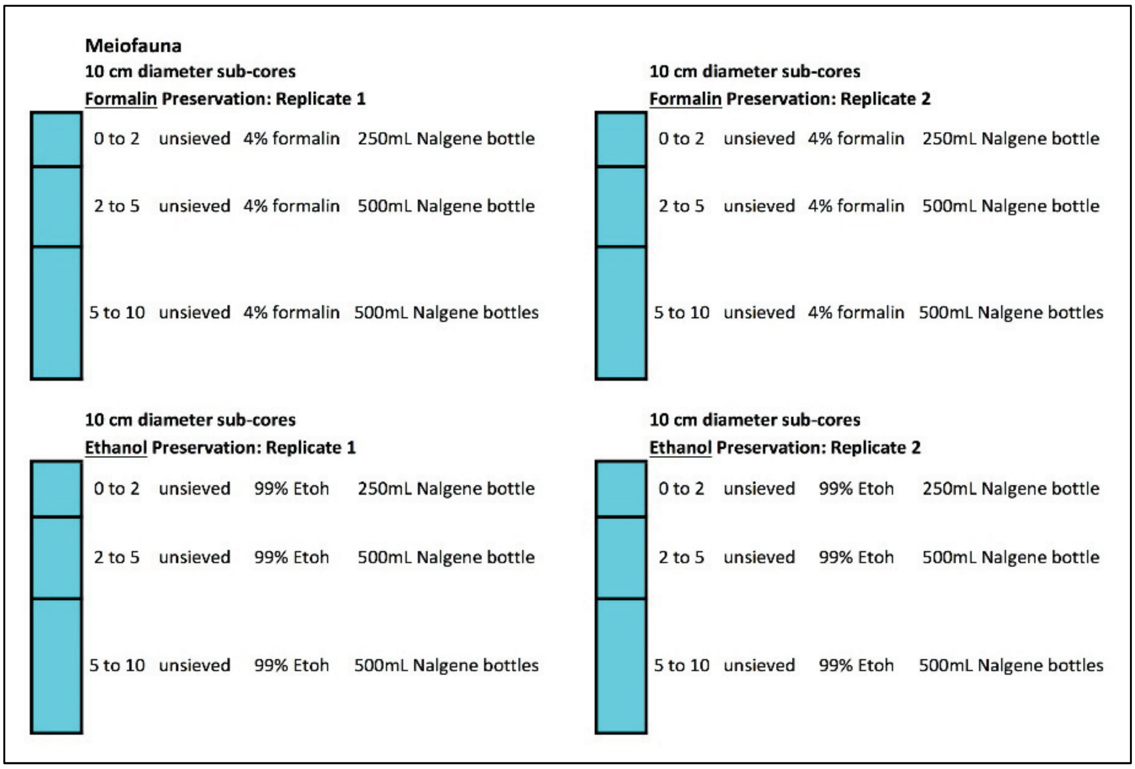


Figure 9.23 Sample Plan – Macro-fauna

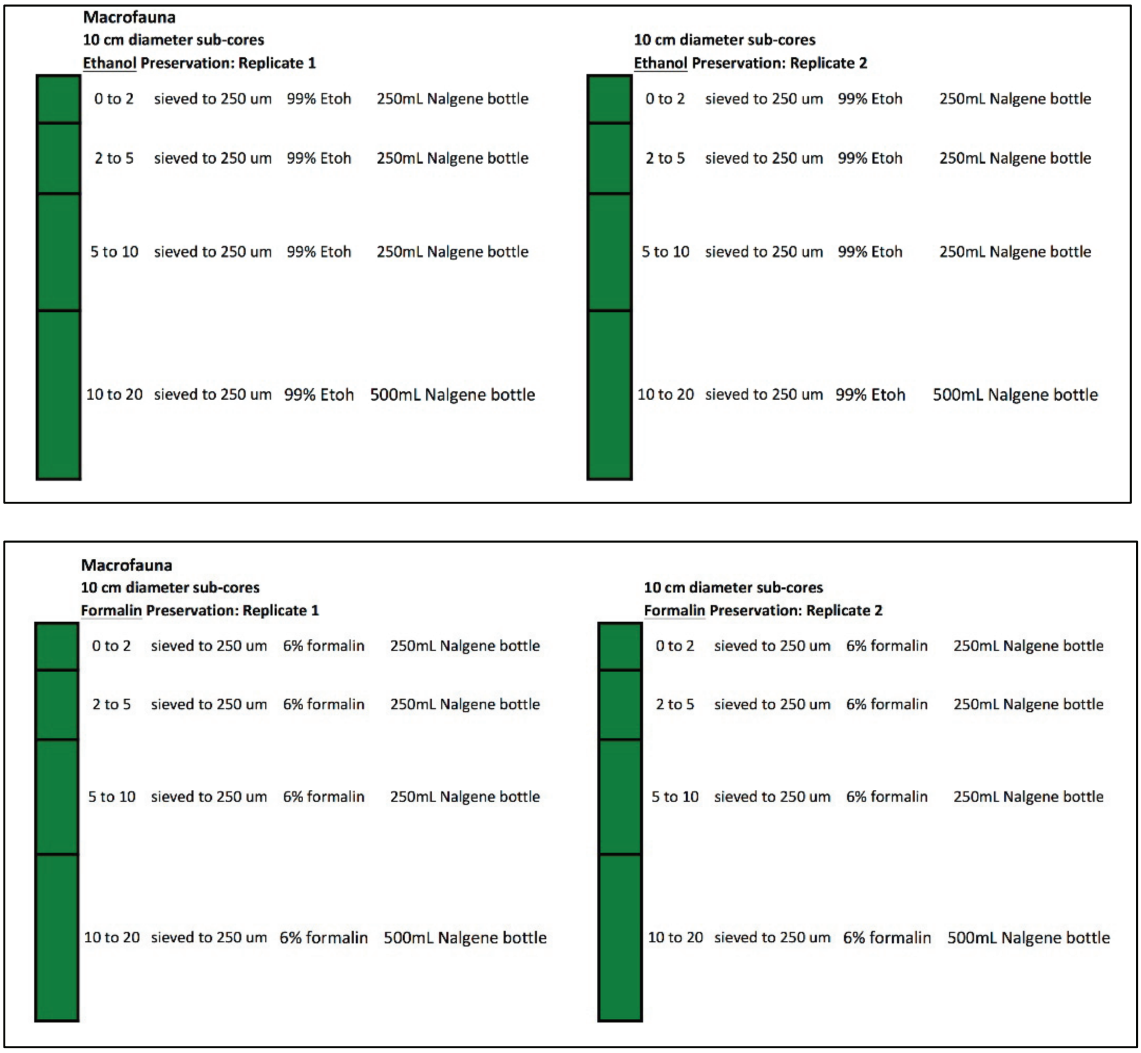
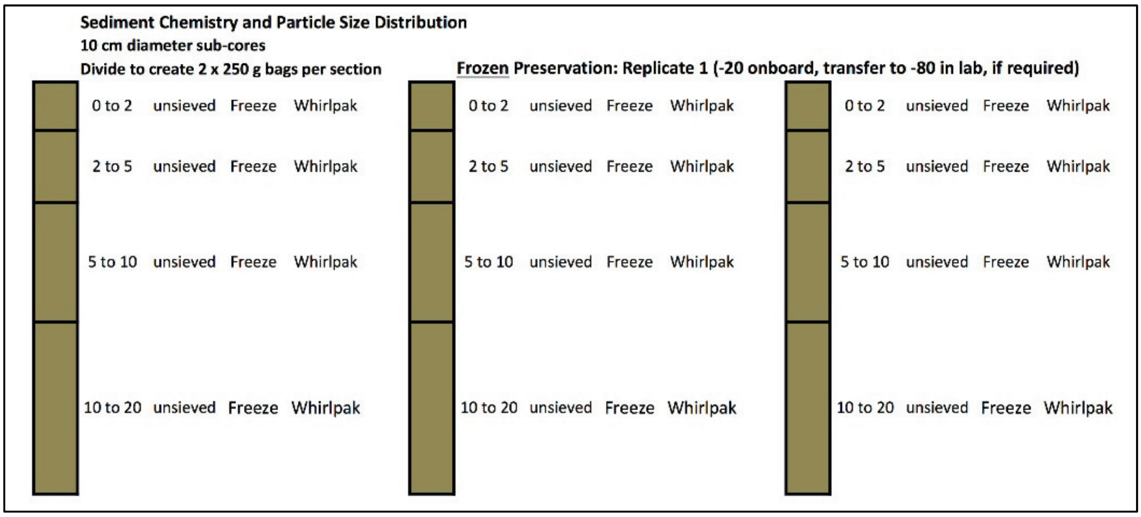


Figure 9.24 Sample Plan – Sediment characterisation



9.3.9 Sediment residue sampling

Most box-cores with good returned sediment had three samples taken after all other sampling was complete:

- Top sample was typically 0-5 cm and comprised any remaining semi-liquid layer and geochemically active layer. Typically very soft and selected by this characteristic.
- Second sample was of more solid sediment typically taken at 5-20 cm.
- Third sample was remaining to base of box, usually a further 10-20 cm down, depending on depth of penetration.
- Each sample weighed between 5 kg and 25 kg and in total about 330 samples were taken, making this the highest volume-weight sample collected and shipped.
- The sediment was taken for use in future geotechnical/engineering studies (e.g. reconstruction for traction and nodule collection bench top trials) and for reference.

9.3.10 Water sampling

Water column samples were collected during CCZ15 as part of the environmental base-line characterisation of the TOML tenement areas in order to meet the recommendations per the ISA document; Environmental Management Needs for Exploration and Exploitation of Deep Sea Minerals. Samples were collected via the Niskin bottle rosette attached to the box-corer (Figure 9.14, Figure 9.25). The Niskin bottle rosette contained 12 x 300 ml Niskin bottles, which were triggered using a pressure sensor. Samples were collected for both infield and on-shore laboratory analysis.

Water sample types collected were:

- Total Metals (TM) - 125 ml sterilised Nalgene container – 1 ml of nitric acid added for preservation (on-shore analysis);
- Total Suspended Solids (TSS) - 1 L sterilised container (on-shore analysis);
- pH and Oxidation-Reduction Potential (ORP) - In-field measurements – approximately 150 ml required to obtain measurements.

The water sampler (Niskin rosette) was programmed with the selected depth strata for full water sampling programme conducted in Area C, D and F and the Niskin bottles set to the open position, each time before deploying the box-core. The water-sampling programme was designed to collect samples from varying depth strata across all areas where box coring was conducted.

Depth strata sampled for the majority of samples collected were:

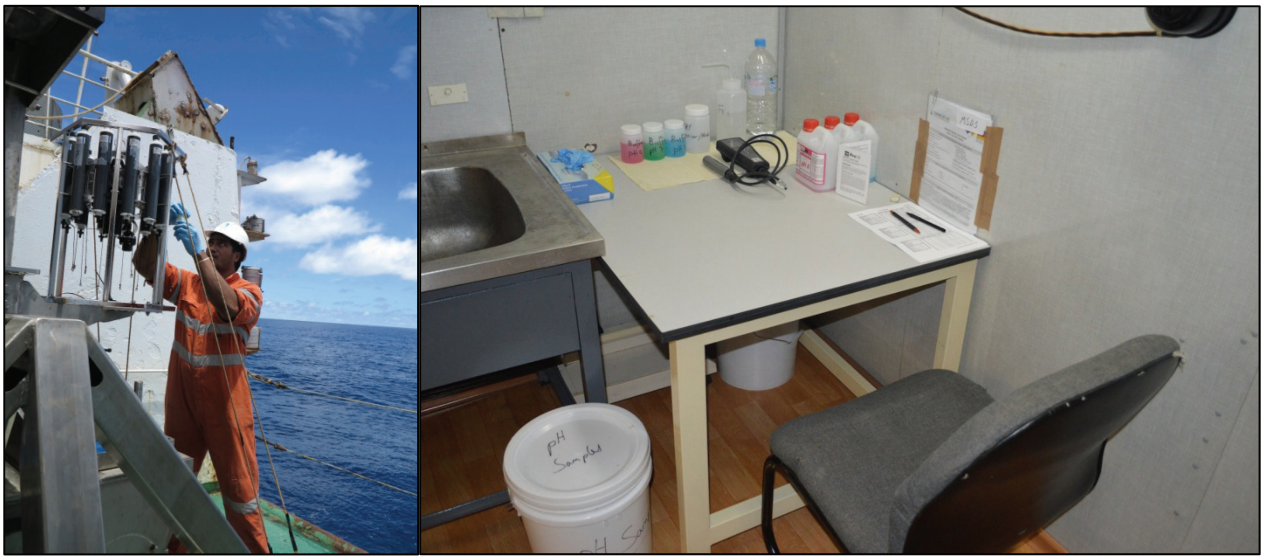
- 50 m
- 200 m
- 500 m
- 1,000 m
- 1,500 m
- 500 m from the seafloor
- 100 m from the seafloor
- 50 m from the seafloor

Upon recovery of box-core and Niskin rosette to deck, the Niskin bottles were processed depending on the sample type being collected. TM and TSS were collected using the appropriate sterilised sample containers and refrigerated at 4°C The pH and ORP samples were collected and taken to the water chemistry laboratory for analysis. Samples were analysed using YSI Pro10 handheld multi-probe with pH and ORP sensors. A three point calibration was conducted on the pH sensor prior to every sampling event.

Niskin bottles were fired during the decent due to the limitations of the device, as there was no way of programming the device to delay firing at the set depth strata on ascent. To minimise the risk of contamination from residue left from previous sample, the box-core was washed out between deployments. Due to commissioning issues the water sampler was not operational until Area C. Therefore, water samples were only collected in Area C, D and F.

All water samples collected for laboratory analysis were priority hand-carried back to Brisbane and shipped to SGS Cairns for analysis.

Figure 9.25 Water Sample Collection and Water Chemistry Laboratory



9.3.11 Water column profiling

During CCZ15, water column profiles were collected as part of the environmental base-line characterisation of the TOML Areas in order to meet the recommendations per the ISA document: Environmental Management Needs for Exploration and Exploitation of Deep Sea Minerals. The majority of water column data were collected via a Mini Autonomous Plume Recorder (MAPR) with the following sensors:

- Temperature (°C);
- Turbidity (NTU);
- Depth (m).

The MAPR was deployed during most operations by attaching it to either the box-core cable (50 m above the box-corer) or the umbilical of the MAK (side-scan) or Neptune (photo-profiler) at 50 m above either instrument, see Figure 9.14-Plates 7 & 9. Upon recovery of the MAPR to deck, these data were downloaded and processed and Excel template.

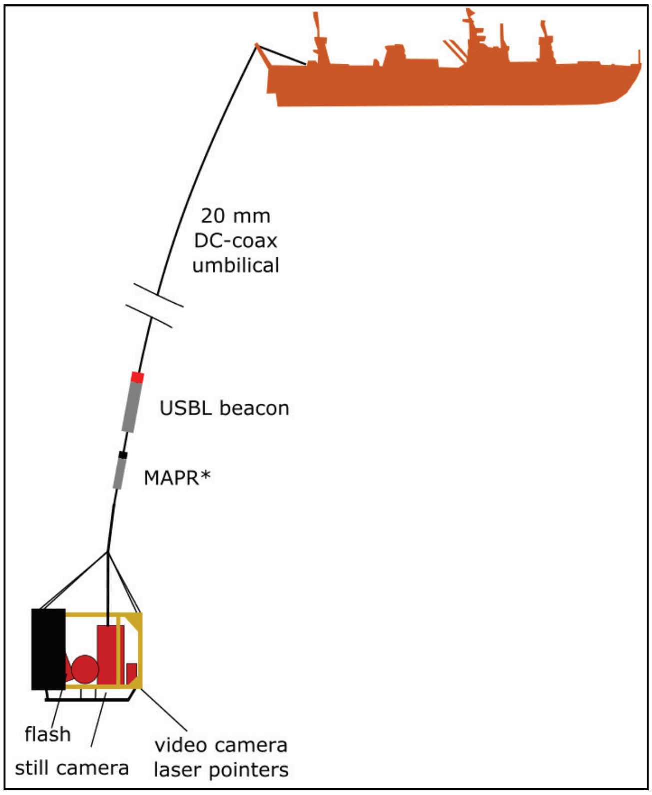
Along with the MAPR, an Aanderaa Seaguard single-point current sensor was deployed on a select number of box-core deployments in Area F.

9.3.12 Photo-Profiling Programme

Photo-profiling was undertaken to provide data on short range continuity of nodules and visual based estimates of nodule abundance for mineral resource estimation. It also provided a census of mega-fauna and macro-fauna for environmental base line measurement and habitat mapping. Finally, it helped calibrate MBES and deep towed sonar results in terms of understanding seafloor rugosity.

Deployment and recovery of the camera was off the stern of the vessel using an umbilical and the vessels aft tow winch (Figure 9.26). The system was deployed just above the seafloor with the winch operator taking line in and line out to compensate partially for vessel heave. Video was streamed constantly to the vessel where it was logged by TOML team into the Nautilus Minerals' proprietary Nautical logging system.

Figure 9.26 Neptune Deployment Schematic



Photographs were taken automatically at a prescribed altitude of 3.5 m above the seafloor, a minimum 30 seconds apart and continually uploaded to the vessel where scientists collected them from the central server and logged them for geology and biology. These were also subsequently logged by the TOML biologist in more detail.

Neptune lines were pre-planned to place the vessel into “prevailing result” where it maintained a forward speed of about 1.2 knots. As the line got longer, more line tended to be fed out and vessel speed tended to increase. Average velocities also tended to increase as the cruise progressed and the team optimised survey settings.

The system’s position was monitored using a 12 kHz USBL beacon except on line CCZ15-F08, where an estimate of position had to be made from line out and vessel position.

Hydrographic surveyor and bridge shared the same navigation display and the vessel was steered so that the profiles never moved more than 1 km off line and typically was well within 500 m of the planned line.

Survey data from the vessel, USBL location of the camera and attitude sensor was collected and subjected to preliminary analysis to learn more about towing dynamics.

Figure 9.27 Neptune Deployment Photographs

9.3.13 Deep Towed Sonar Programme

YMG's MAK-1M deep towed system was brought on the CCZ15 cruise primarily to map and characterise the seafloor bathymetry in detail via its 30 kHz side scan system. The system also provided useful data on seafloor composition from its 5 kHz sub-bottom profiler and on seafloor surface survey from its altimeter-USBL survey data.

Essential operation was as follows:

- Deployment and recovery of the sled and depressor was off the stern of the vessel (Figure 9.28, Figure 9.29)
- MAK lines were pre-planned to place the vessel into prevailing result where it maintained a forward speed of about 1.5 knots
- The system's position was monitored using an integrated 12 kHz USBL beacon and altimeter
- The system was towed behind a depressor weight about 100 m above the seafloor with slight elevation changes to follow the seabed. Speed of towing was limited by ping rate and data quality
- Hydrographic surveyor and bridge shared the same navigation display and the vessel was steered so that the sled never moved more than several hundred metres off line
- All processing through to delivered products was done on-board by the YMG MAK team.

As with the Neptune photo-profile systems, analysis of the sled versus ship position as well as some attitude/MAPR sensor data provided information on deep tow dynamics that might be of help in the design of future towed systems (e.g. for the Nautilus mining concept).

Figure 9.28 MAK Deployment Schematic

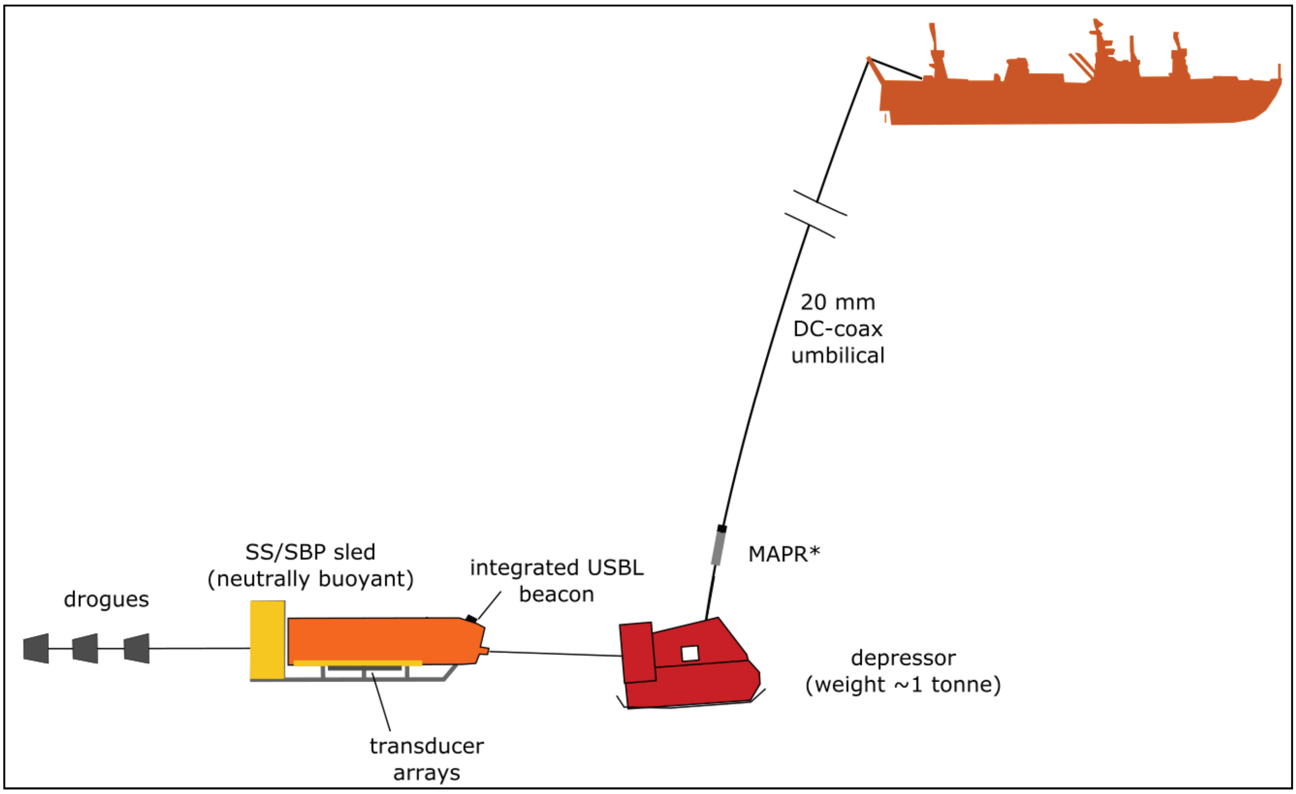
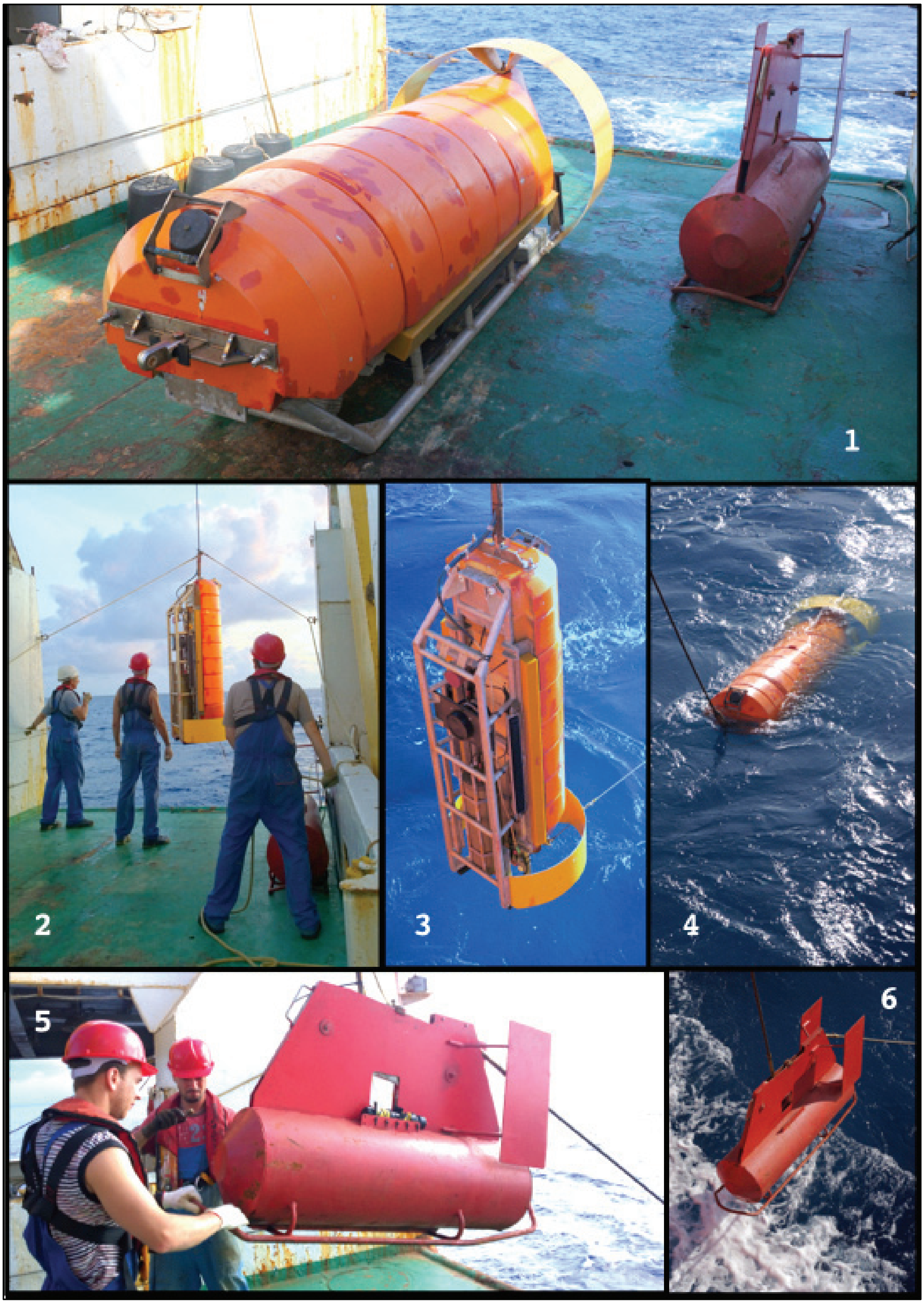


Figure 9.29 MAK Components and Deployment



9.3.14 Dredging Programmes

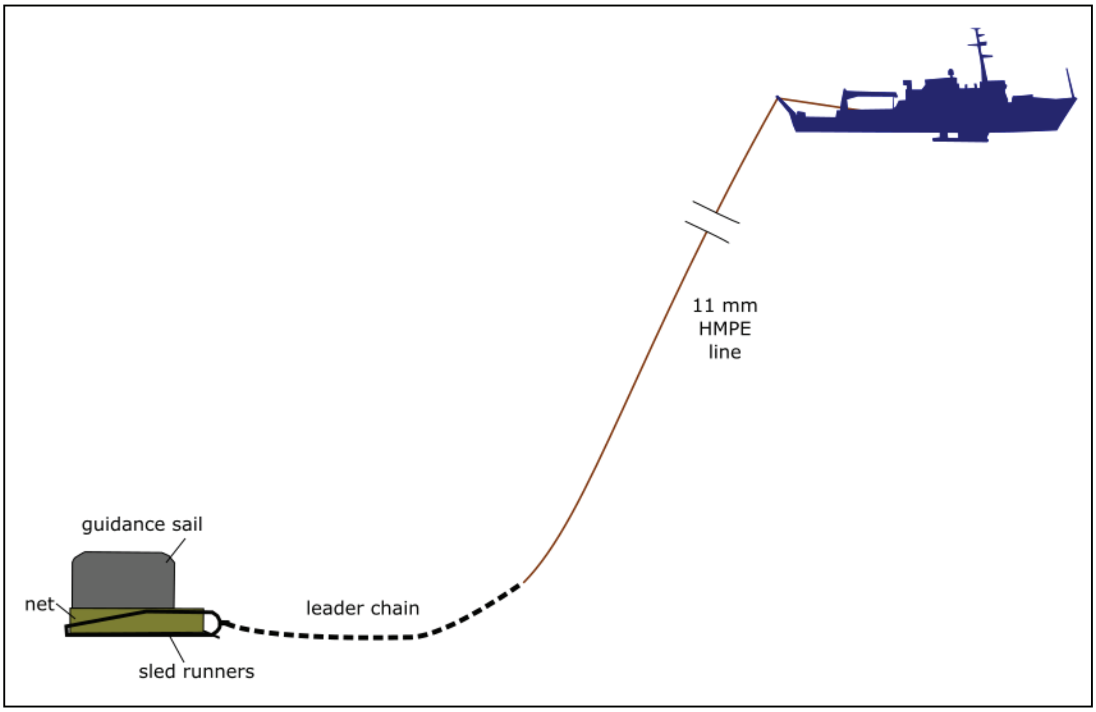
Dredging was carried out during both the CCZ13 and CCZ15 cruises, albeit with different methodologies. The intent was to collect sample for metallurgical test work, including chemical whole rock analysis.

9.3.14.1 CCZ13 Epibenthic sled

An epibenthic sled was designed and built for the CCZ13 dredging (Figure 9.30, Figure 9.31). An epibenthic collector was chosen so as to:

- Be able to be set up to skim the seafloor collecting epibenthic and inbenthic located nodules with minimum mud;
- Be more able to clean itself of mud;
- Consequently, impact the environment less.

Figure 9.30 Epibenthic sled Deployment Schematic



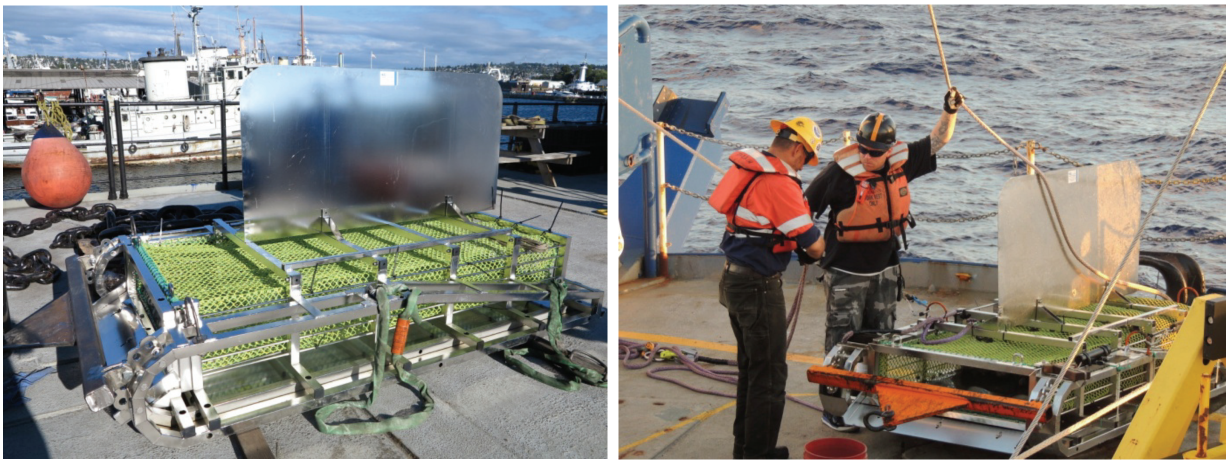
The sled was typically equipped with a camera and lights as well as an attitude sensor. Data from these were recovered and analysed at the end of each deployment.

Sample handling procedures essentially comprised weighing on recovery, followed by screening (+/- 2 and 3/8" or approximately 6 cm) and photography of all, or if an excess of material for the photo sheet, a typical sub-sample. Many of the nodules were broken from their time in the dredge.

After some trial and error the approach generally taken to dredge was:

- About 1.5 km before the edge of the target zone, steam into the wind at 1.5 to 2.5 knots paying out line to 6-7 km
- On reaching the bottom or the target line out slow to slowest effective forward speed (i.e. having available steerage). this was typically 0.3-0.8 kt speed over ground
- Use line out to regulate load as transmitted to the load cell
- Run the load between minimum (line slack) and maximum loads (lift off), decreasing the range around what was judged to be the effective towing load (this was typically a range of only about 40-80 kg).
- Once or twice during the deployment (later increased to 3-4 times) lift and lower the sled using the vessel speed to wash out excess mud that might be filling the sled (termed a "tea-bag" manoeuvre). Minimise use of the winch to avoid tipping the nose of the sled and losing sample.
- End the dredge by starting line in and speed up the boat to 2 knots

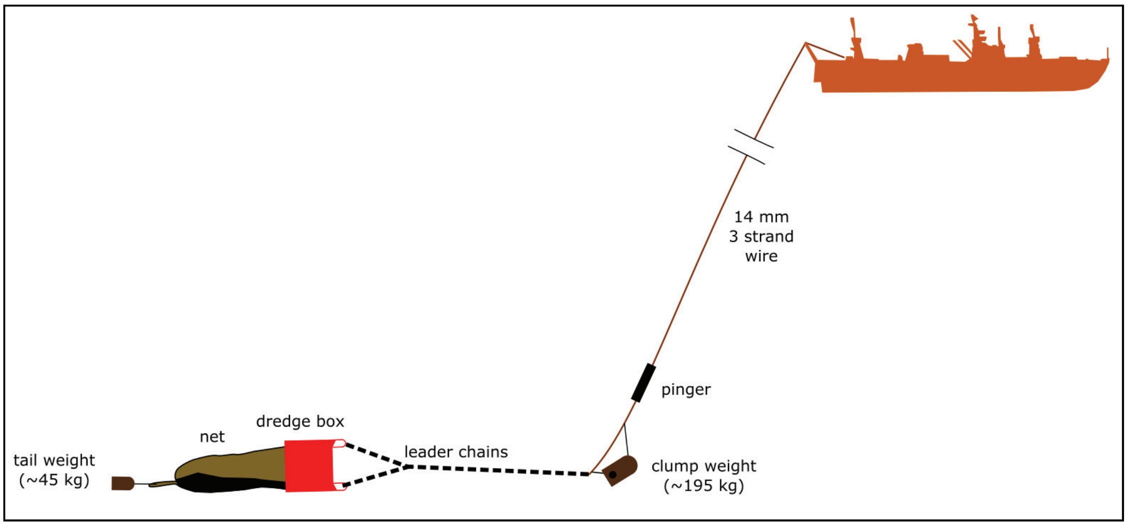
Figure 9.31 Photos of epibenthic sled



9.3.14.2 CCZ15 Galatea dredge

The dredging approach was changed in CCZ15 for reasons of practicality.

Figure 9.32 Galatea Dredge Deployment Schematic



The sample locations were picked to ensure that between the sampling of this cruise and the CCZ13 cruise, at least one dredge sample was taken in each contract area. Dredges were also the quickest and most effective way to sample Area A, albeit in a non-quantitative manner.

The process of dredging involved:

- Dredge lowered at 0.5 m/s for first 200 m then 1 m/s to the bottom, then slowed to 0.5 m/s till touching the seabed.
- Recovery to surface all the way at 1 m/s (full speed).
- The vessel maintained forward speed into the weather at all times (~0.8-1.3 knot SOG was OK no change in speed needed);
- Winch speed slowed but not stopped and the pinger trace height (~10 m) used to estimate when the dredge touches.
- Leader chain and bridle were about 4-5 m long to ensure dredge is pulled parallel to the seabed.
- “Teabag” manoeuvres used to clean the dredge between landings (each landing is about 1 minute and after lifting at about 0.7 m/s to 100 m the cleaning takes about 2-3 minutes before return to the seafloor at 0.5 m/s).
- 3-7 “teabags” were carried out depending on weight of sample required.