3. Results

3.1 Sediment chemistry

3.1.1 Polycyclic aromatic hydrocarbons

Twenty-eight off-reef sediment samples were collected and analysed by the University of Waikato. Sixteen samples were collected from sediment flats around Otaiti Reef, six from sediment flats around Mōtītī and six from sediment flats adjacent to Bay of Plenty coastal beaches. Mean total PAH content was 0.146 ± 0.086 mg.kg⁻¹ for sediments in the Otaiti Reef 500m strata, 0.022 ± 0.010 mg.kg⁻¹ in the 1000m strata, 0.003 ± 0.001 mg.kg⁻¹ in Mōtītī samples, and 0.001 ± 0.000 mg.kg⁻¹ in coastal beach samples (Figure 4).

![Graph showing PAH levels](image)

Figure 4. Mean total PAH levels measured in sediments adjacent to Otaiti Reef, Mōtītī Island and coastal beaches. Otaiti off-reef sediments were collected at a distance of either 500m or 1000m from the wreck of the MV Reno.

Total PAH was variable within sampling strata (Figure 5). Of the sixteen Astrolabe samples, sediment total PAH was below detection levels at four sites, less than 0.01 mg.kg⁻¹ at two sites, between 0.01 and 0.099 mg.kg⁻¹ at seven sites, between 0.1 and 0.5 mg.kg⁻¹ at two sites and was greater than 0.5 mg.kg⁻¹ at a single site (Figure 5).
The greatest total PAH readings (0.1-0.72 mg.kg⁻¹) were from samples collected in the inner sampling strata (500m), immediately to the east and west of the wreck of the *Rena* (Figure 6).
PAH readings at outer strata (1000 m) sampling locations were generally less than those recorded closer to the wreck (Figures 4, 5 and 6). However, intermediate PAH levels were recorded to the north-west and south-east of Otaiti Reef at a distance of 1000m. Mötiti island total PAH levels were below detection limits at two sites and below 0.006 mg.kg-1 at the remaining four sites. For the coastal beach subtidal sediment samples, PAHs were below detection limits at Matakania Island and Ōmanu and were 0.002 and 0.003 mg.kg-1 for Pāpāmoa and East Cape (Figure 5).

Total PAH levels in sediment collected by SCUBA divers on Astrolabe Reef were for the most part an order of magnitude greater than levels detected in off-reef sediments (Figures 4, 5 and 7). While off-reef sediment total PAH levels ranged in magnitude from non-detectable to 0.72 mg.kg-1 (Figure 5), on-reef PAH levels averaged 4.65 ± 1.94 (s.e.) mg.kg-1 with a range of 0.08–27.79 mg.kg-1. The highest total PAH reading (27.79 mg.kg-1) was from the Astro-2 site, located in shallow waters between the bow and stern of the wreck (Figure 7). High PAH levels (5.15–12.82 mg.kg-1) were also detected at sites Astro-4, 5 and 6, while Astro-1, 3, 7 and 8 showed a lower level of contamination (0.40–1.92 mg.kg-1). The Astro-1 sediment sample showed the lowest total PAH content of all on-reef samples (0.03 mg.kg-1) and was comparable to some of the more contaminated off-reef sediment samples.

![Figure 7. Total PAH levels measured in sediments on Otaiti Reef.](image)

RENA Environmental Recovery Monitoring Programme
3.1.2 Metals

Thirty one sediment samples collected on or adjacent to Otaiti Reef were analysed for metal content. Sixteen samples were collected from subtidal sediment flats at a distance of either 500m or 1000m from the wreckage of the Rena (Figure 1). Another fifteen samples were collected on SCUBA from Otaiti Reef itself (Figure 2). For all of the 24 metals for which analyses were conducted, higher levels were recorded in sediments collected on the reef itself compared with sediments collected from adjacent subtidal sediment flats (Figure 9a-x). In many cases, on-reef sediments were an order of magnitude richer in metal content than off-reef sediments (e.g. Mg, Se, Ba, Ni, Ti, Zn, As). Iron (Fe) was the only metal for which on-reef and off reef sediment samples were similarly enriched (Figure 9q).

Levels of metal enrichment were highly variable from site-to-site (Figure 9). While there was no clear pattern of specific sites being more enriched than, for many of the analyses conducted, enrichment was greatest at site Astro-6, 7, 8 and 9. These sites are located to the south and northwest of the wreckage of the ship (Figure 2). In the absence of comparable data from nearby reefs or islands, it is difficult to assess (a) whether the pattern of metal rich on-reef sediments and metal poor off-reef sediments is typical of reefs and islands in the Bay of Plenty, or (b) whether the levels of metal enrichment observed in sediments both on and off the reef are typical of sediments throughout the region. However, it does appear that aluminium, zinc and copper may be elevated above what we would consider typical of coastal sediment (Figure 9d, n and r). In particular, copper levels at on-reef sites Astro-1 and Astro-2 were exceptionally high (3550 and 2127 ppm; Figure 9n). (See also Chemistry Report 1f-9, Hendy, 2013).
i. V-51

j. Ni-60

k. Sr-88

l. Hg-202

On-reef sediments

500m from wreck

1000m from wreck

Off-reef sediments

ppm
Figure 9. Metal levels measured in sediments on and adjacent to Otaiti Reef. Astrolabe off-reef sediments were collected at a distance of either 500 m or 1000 m from the wreck of the MV Rena.
3.2 Invertebrate chemistry

3.2.1 Polycyclic aromatic hydrocarbons

Of the 15+ invertebrate species collected to date from Otaiti Reef, chemical analyses have only been performed on the rock lobster, *Jasus edwardsii*, the sea urchin, *Evechinus chloroticus*, and black and yellow footed paua, *Haliotis iris* and *H. australis*. Other specimens including chitons, limpets, topshells, sea cucumbers, crabs and sponges are in storage at the University of Waikato Coastal Marine Field Station and may be analysed at a later date. Completed analyses are summarised below.

**Rock lobster:** (Two specimens) A total PAH of 0.0126 mg.kg⁻¹ (from Astro-7) was recorded in a combined liver and muscle tissue sample taken from the only rock lobster captured from Otaiti Reef (Figure 10). A single specimen from Mōtītī returned a slightly higher reading of 0.0203 mg.kg⁻¹.

![Graph showing PAH levels for rock lobster, paua, and scallops](image)

*Figure 10. Total PAH levels in rock lobster, paua and scallops collected from Otaiti Reef and nearby islands. Bracketed numbers above columns indicate the total number of specimens analysed at each location.*

**Urchins:** (33 specimens analysed from 17 sites at six locations). A total of 17 sea urchins from Otaiti Reef were analysed for PAH contamination. Gonad total PAH levels ranged from 0.006 to 0.3 mg.kg⁻¹ while gut sample PAH ranged from 0.009 to 24.2mg.kg⁻¹ (Figure 11). Contamination of urchin gonads was detected at all Astrolabe sites. Average gonad PAH content was 0.057 ± 0.019 mg.kg⁻¹ (± s.e.) and was less than gut PAH content (averaging 1.58 ± 1.42 mg.kg⁻¹ (± s.e.) for 14 of the 17 urchins analysed from Otaiti Reef. At sites Astro-2 and Astro-3, between the bow and stern of the wreck, gonad PAH contamination was an order of magnitude greater than at other locations on Otaiti Reef (Figure 2). Gut total PAH content of the only urchin analysed at site Astro-2 was 24.2 mg.kg⁻¹, more than 26x the contamination level recorded for any other urchin gut on Otaiti Reef. Moderately high PAH levels were also recorded at sites Astro-1, Astro-2, Astro-4, Astro-6 and Astro-7.
Another sixteen urchins (six from Mōtītī, two from Schooner Rocks, three from Plate Island, three from Karewa and two from East Cape) were analysed for PAH contamination. Similar levels of contamination were recorded in specimens from Mōtītī and other locations (offshore islands and East Cape; Figure 10) with gonad and gut PAH levels averaging 0.026 ± 0.007 mg.kg⁻¹ (± s.e.) and 0.030 ± 0.007 mg.kg⁻¹ (± s.e.) at Mōtītī and 0.023 ± 0.001 mg.kg⁻¹ (± s.e.) and 0.034 ± 0.006 mg.kg⁻¹ (± s.e.) elsewhere. On average PAH levels in Otaiti urchin gut and gonad samples were 60 times (gut) and two times (gonad) higher than levels recorded in urchins collected elsewhere.

**Paua:** (Eight specimens analysed from seven sites). Total PAH contamination in paua ranged from 0.003 to 0.0571 mg.kg⁻¹ (Figure 10). Paua were rare on Otaiti reef with single individuals found only at four sites. Yellow footed paua (H. australis) were found at Astro-2 and Astro-4 with muscle total PAH measurements of 0.026 and 0.0095 mg.kg⁻¹ respectively. Black footed paua (H. iris) were found at Astro-6 and Astro-7 with muscle total PAH measurements of 0.0198 and 0.0571 mg.kg⁻¹. Black footed paua were also collected at Mōtītī and East Cape with total PAH levels of 0.007 ± 0.003 and 0.016 ± 0.006 mg.kg⁻¹ (± s.e.) respectively (Fig.10).

**Scallop:** (Single specimens analysed) A single scallop was collected to the south-east of Mōtītī Island. It had a PAH content of 0.022 mg.kg⁻¹.

### 3.3 Fish chemistry

#### 3.3.1 Polycyclic aromatic hydrocarbons

The muscle tissue of fourteen fish collected at six locations (Otaiti Reef, Mōtītī, Karewa, Plate Island Schooner Rocks and Okaparu) was analysed for PAH contamination. The fish were blue cod (n=4; Parapercis colias), scorpion fish (n=1; Scorpaena cardinalis), dwarf scorpion fish (n=1; Scorpaena papillosus), sea perch (n=1; Helicolenus percoideus), red moki (n=2; Cheilodactylus spectabilis), leather jacket (n=1; Parika scaber), spotted wrasse (n=1; Pseudolabrus celidotus) and hiwihwi (n=1; Chironemus marmoratus). Total PAH was highest in the blue cod collected at Astro-1 (0.265 mg.kg⁻¹). The scorpion fish and sea perch analysed from the same site had total PAH levels of 0.027 mg.kg⁻¹ and non-detectable, respectively. PAHs were also below detectable levels in the red moki from Astro-4 while the leather jacket
from Astro-8 had a total PAH content of 0.036 mg.kg\(^{-1}\) and dwarf scorpion fish from Astro-9 had a PAH content of 0.012 mg.kg\(^{-1}\) (Figure 12). PAH levels in fish collected at other locations were variable but comparable to fish from Astro-8 and 9, averaging 0.035 ± 0.007 mg.kg\(^{-1}\) (± s.e.).

![Graph showing PAH levels in fish collected from different locations.](image)

**Figure 12.** Total PAH levels in fish collected from Otaïti Reef and nearby islands.

### 3.4 Reef habitat monitoring

Benthic communities were described in a total of one hundred and ten 1m\(^2\) quadrats. Urchin abundance, *E. radiata* coverage and stipe density and coverage of other brown algae were quantified in each of ten quadrats at the eleven sampling stations. Coverage and abundance indices for urchins and kelp were lowest in quadrats immediately adjacent to the ship’s hull which may be indicative of physical and/or chemical perturbation. However, as our monitoring data is limited and pre-grounding data non-existent it is difficult to determine the mechanisms driving these observations. The results of reef habitat monitoring are described below.

#### 3.4.1 Urchin abundance

Urchins were absent at all stern sampling stations except for the port-stern 50m station where mean urchin density was 0.3 m\(^{-2}\) (Figure 13). While urchins were more abundant in the shallower waters of the bow sampling stations (0.7-3.2 m\(^{-2}\)), they were largely absent in shallow stations adjacent to the wreckage (0.1-0.2 m\(^{-2}\)).

#### 3.4.2 Kelp

*E. radiata* coverage and stipe density was low at all starboard-stern sampling locations (0.5 – 1 stipes m\(^{-2}\)) and absent at the port-stern 0m station (Figure 13). Stipe density was greater at the 50m and 100m stern-port stations (2.7 – 4.6 stipes m\(^{-2}\)). In the shallower waters about the *Rena’s* bow *E. radiata* was only recorded at three stations and was most abundant at the station most distant from the ship’s hull.
3.4.3 Brown algae

Other brown algae (mostly *Carpophyllum* spp.) were rare at the deeper stern sampling stations. In shallower waters, coverage of brown algae was relatively high to port and starboard of the hull (0 – 24%; Figure 13).

![Graphs showing urchin density, kelp stipe density, kelp coverage, and brown algae coverage on port and starboard sides of the ship.](image)

Figure 13. Abundance of urchins, stipe density and coverage of kelp and coverage of other brown algae at monitoring stations located 0m, 50m and 100m from the port and starboard of the wreck of the MV *Rena*. 