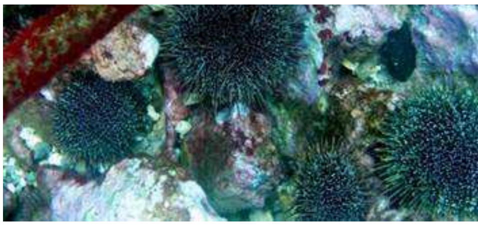


Rena

ENVIRONMENTAL RECOVERY MONITORING PROGRAMME

2011-2013

Te Mauri Moana

Rena Recovery
Long-term Environmental Recovery Plan

Mihi

Tukua te wairua kia rere ki ngā taumata
Hai ārahi i ā tātou mahi
Me tā tātou whai i ngā tikanga a rātou mā
Kia mau kia ita
Kia kore ai e ngaro
Kia pupuri
Nau mai e ngā hua
o te wao
o te ngakina
o te wai tai
o te wai Māori
Nā Tane
Nā Rongo
Nā Tangaroa
Nā Maru
Ko Ranginui e tū iho nei
Ko Papatūānuku e takoto nei
Tuturu whakamaua

The Rena Environmental Monitoring Programme was conducted by the following organisations.

COVER PHOTOS:
From top, left to right:

1. Mt Maunganui. *Source: Tourism Bay of Plenty.*
2. CV Rena run aground on Otaiti (Astrolabe Reef) - January 9, 2012. *Source: Maratime New Zealand.*
3. NZDF reserves cleaning Papamoa Beach - October 13, 2011. *Source: New Zealand Defence Force.*
4. Research diver above Rena wreckage on Otaiti (Astrolabe Reef). *Source: University of Waikato.*
5. Testing larval kingfish for the effects of fuel oil and oil dispersant. *Source: Bay of Plenty Polytechnic.*
6. Dissection of crayfish for analysis of fuel oil contamination. *Source: University of Waikato.*
7. Sea urchins and Rena debris on Otaiti (Astrolabe Reef). *Source: University of Waikato.*

Executive Summary

Abstract

This report summarises the results of the scientific sampling and monitoring programme that commenced following the grounding of the CV Rena on Otaiti (Astrolabe Reef) on October 5, 2011. A comprehensive environmental monitoring programme was undertaken between October 7, 2011 and January 24, 2013 with continued monitoring of kai moana species along key beach locations until early October 2013, effectively constituting 24 months of surveillance. A small amount of monitoring on and around Otaiti was completed in November 2012 when an opportunity permitted access amidst salvage activities. This latter monitoring has provided a backdrop for an additional and more comprehensive programme directed specifically at the Otaiti Reef shipwreck site and adjacent islands, the results of which will be reported elsewhere. Findings conveyed within this present report are based on data collected as part of the whole of Bay of Plenty environmental recovery programme as originally outlined in the Ministry for the Environment "Rena Long-Term Environmental Recovery Plan", December 2011. It is pertinent to note that this plan was designed prior to the breakup and sinking of the vessel and was oriented toward the environmental concerns at the time associated with heavy fuel oil around the coast.

The research presented in this report comes from one of the most comprehensive, multi-disciplinary studies ever conducted in response to a marine pollution incident. It is unique in two ways:

- Immediately after the CV Rena hit Otaiti Reef and before contaminants were lost from the ship, marine scientists collected quantitative information of high relevance to the ecosystem from around the reef, other offshore islands and the adjacent coastline. This information gave a good picture of the environment's immediate 'pre-Rena state', and helped scientists to track changes to the Bay of Plenty environment relative to this initial state.
- The survey design and philosophy were steeped in linkage to Matāuranga Māori. The goal of the Rena Recovery Plan is to "restore the mauri of the affected environment to its pre-Rena state." (Ministry for the Environment, 2011). The goal of this scientific work is to provide the information that will assist with and inform that restoration.

Additional information will be provided in separate reports by the five cultural impact assessments undertaken by iwi, a mauri assessment of the Maketū rohe and a Matāuranga study.

This report does not aim to give a comprehensive assessment of the long-term environmental effects to the mauri which involves other cultural considerations, nor does it provide a complete assessment of the complex socioeconomic and cultural interactions surrounding the Rena grounding. As a synopsis of the collective monitoring programmes relating to Rena's environmental impact, this report provides insights into the potential impacts on the mauri of the Moana a Toi (Bay of Plenty region). These insights are for integration within a wider assessment of effects and responses. This executive summary provides a chronology of the Rena incident and delivers the key findings of the collective monitoring programmes as they relate to the Bay of Plenty coastline and a preliminary assessment of Otaiti. It also provides a brief synopsis of each of the fifteen monitoring and research programmes that are part of the Rena Long-term Environmental Recovery Plan. These synopses are intended to be understood by an audience of non-scientists. Accordingly, the level of

detail presented here is less than that contained within each of the subsequent reports relating specifically to the individual monitoring programmes which are largely focused on the range of ecosystems and habitats within the Bay of Plenty. Additional scientific assessment of contamination on Otaiti (Astrolabe Reef) has been coordinated by the Rena owners and BECA, in collaboration with the University of Waikato, Bay of Plenty Regional Council, Ministry for Primary Industries and Bay of Plenty District Health Board. The results of that survey will be published separately.

Mauri

I te timatanga ko te kore

Ko te po

Na te po ka puta ko te kukune

Ko te pupuke

Ko te hihiri

Ko te mahara

Ko te manako

Ka puta I te whei ao

Ko tea o marama

Tihei mauri ora

Mauri is the life force, the life essence contained in resources both animate and inanimate. Mauri binds the physical world to the spiritual, and despite its diversity, the world is unified through mauri (Love et al., 1993). Mauri therefore encompasses the environment holistically as one interlinked and interrelated system.

Mauri is not isolated in time and cannot be defined only in the present. Mauri connects the past with the future and therefore protects and preserves systems for future generations. In a more holistic sense, future generations are not limited to man alone. Whakapapa incorporates the process of change that features in all environmental systems.

Mauri is linked to the physical and spiritual integrity and resilience of the system. Mauri therefore can be related to the maintenance, protection and balance of natural equilibria, both physical and spiritual. The natural, healthy and proper state of any system is a state of balance (Williams, 2001). Environmental systems naturally fluctuate; a system in balance has the ability to correct, reorder, re-establish and repair. However, extreme impacts or long-term cumulative impacts can alter the balance of a system, which can inhibit the natural ability to self-manage. To restore the mauri or natural balance of the system in these cases requires long-term assistance.

The complex nature of environmental systems means that when addressing the preservation or restoration of mauri, the wider system/s and relationships must be recognised. In terms of tangata whenua, restoring the mauri of an environmental system directly links to preserving the cultural and traditional relationships both physical and spiritual. The Rena project has embraced a collaborative approach, where hapū, iwi and the wider community have had a valued input and involvement in the recovery and on-going environmental monitoring.

Key Findings

By world standards, the oil spill resulting from the Rena grounding was relatively minor. Also by world standards, the New Zealand coastal environment is relatively pristine. An oil spill on an otherwise uncontaminated coastline in an area of significant national and international distinction for fisheries, recreation and tourism therefore constitutes a major maritime disaster. The initial concern of iwi, government, commercial stakeholders and the wider public following the Rena grounding and oil spill was that oil would have a long-lasting and negative impact on beaches, reefs and fisheries. The results of the monitoring and research programmes reported here and in accompanying documents show that these fears can for the most part be put to rest. However, it cannot be stated that the Bay of Plenty coastal environment has returned to its 'pre-Rena state'. There remains some evidence of Rena-related oil contamination in marine organisms, including kai moana, on Bay of Plenty beaches and inside Tauranga Harbour although at levels not likely to cause public health or wider environmental concerns. There was also preliminary evidence of fuel oil and metal contamination of sediments and of some marine organisms on and around Otaiti, particularly in the vicinity of the Rena wreckage (this is now the subject of intensive survey and will be reported on elsewhere). Summarised below are the key findings of the collective monitoring programmes as they relate to the Bay of Plenty coastline, offshore reefs and to a lesser extent, Otaiti (figures 1 and 2).

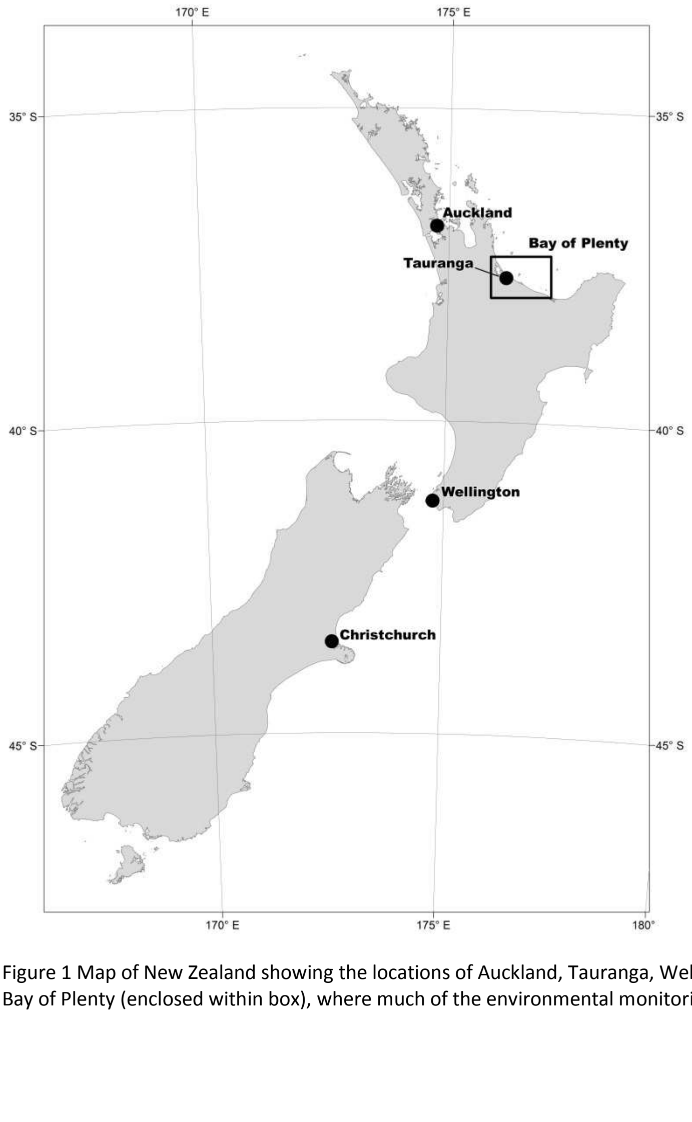


Figure 1 Map of New Zealand showing the locations of Auckland, Tauranga, Wellington, Christchurch and the Bay of Plenty. The western Bay of Plenty (enclosed within box), where much of the environmental monitoring has taken place, is shown in more detail in figure 2.

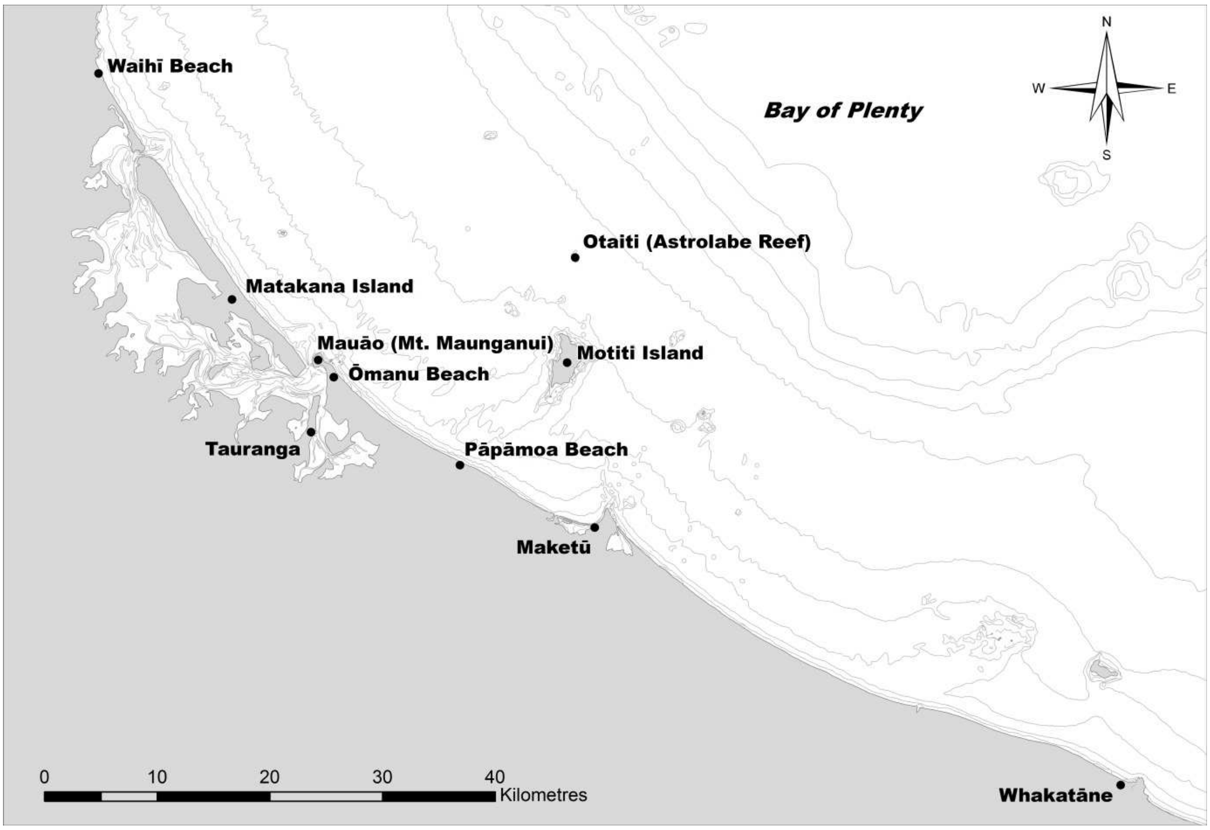


Figure 2 Map of the western Bay of Plenty where much of the environmental monitoring has taken place. Key places and sampling locations are labelled

Bay of Plenty coastline

There is now little evidence of oil or tar balls around the Bay of Plenty coastline. Oil washed up on rocky reefs has largely disappeared and oil residue has not been found in coastal sediments from almost all of the sediment cores taken around the Bay of Plenty. Traces of oil at Ōmanu beach have been found in recent (August 2013) examinations of core samples. However, none matched the complete Rena fingerprint. Levels of polycyclic aromatic hydrocarbons (PAHs) found were just above detection limits for Hill Laboratories, hence extremely low. However, oil spots and other debris from the shipwreck and containers do occasionally still wash ashore. The environmental significance of these more recent events is deemed to be relatively minor as the quantities of oil and debris observed at each location are small (locations of recent oiling include the northern tip of Mōtītī Island, parts of Pāpāmoa Beach and Maketū, and Whangaparaoa near East Cape). The more persistent presence of plastic beads has not been examined in this part of the Rena Recovery Programme. Where oil does come ashore on Bay of Plenty beaches, it is now a mixture of small amounts of newly released heavy fuel oil (HFO), presumably from within the Rena hull as may be expected, and older tar balls released from the ocean floor during storm events.

An investigation of the effects of the spilt oil on coastal marine organisms in the Bay of Plenty indicates that the majority of organisms have survived the Rena incident with no evidence of catastrophic die-offs recorded for any species. Sublethal effects of the oil spill on coastal marine organisms were also not apparent, as fluctuations in organism abundance and size are not correlated with the amount of spilt oil coming ashore at particular locations. However, there was evidence of continued, albeit very low, levels of Rena-sourced oil contamination in some marine organisms (up until January 2013), both on the open coast beaches and inside Tauranga Harbour. No overt impacts of this oil contamination on the viability or reproductive ability of these organisms have been identified from kai moana distribution and abundance surveys, although lower counts of tuatua are reported from the second year winter sampling programme completed in early October 2013. Given that patterns of abundance for this shellfish species do not reflect any adverse effect from high oil impact beach regions, it is surmised that the results reflect the naturally patchy and highly variable distribution of this species in space and time. The reproductive health of tuatua was additionally monitored by histological examination of gonads and no adverse effects were detected. As of October 2013, further work continues with laboratory research examining the sublethal effects of oil on metabolic functioning and other cellular processes in fish species.

Some work was carried out in response to the use of Corexit 9500 offshore. The environmental effects of Corexit 9500 and Rena heavy fuel oil (HFO) in the open ocean can only be surmised as no sampling was possible on dispersant application. However, given the high dilution with strong offshore wind conditions, the effects are regarded as being negligible. To further explore possible effects on fishes, especially larval fishes, further laboratory work was carried out on kingfish larvae. Again, although toxic effects could be demonstrated at high Corexit concentrations, likely field concentrations of the time and the non-engagement with HFO are likely to have had a negligible effect on any larval fishes present. As of October 2013, further work on a range of commercial fin fish species including snapper and flatfish, are being undertaken with extended research programs.

It would be prudent to continue biological monitoring at selected coastal locations where tar balls and other debris continue to come ashore. Continued monitoring will help identify any longer term sublethal impacts of the oil spill that might become apparent over extended temporal scales and allow for further assessment of the effects of this grounding event on marine organisms including kai moana.

Otaiti (Astrolabe Reef)

Based on a very limited data set acquired during this environmental programme, contamination of sediments and some marine organisms on and around Otaiti, particularly in the close vicinity of the ship's hull, appears substantial. The data available are minimal because scientists had limited access to Otaiti for the purpose of sample collection on account of the active salvage program. Fuel oil contamination was recorded in sediments around the wreck and on sediment flats adjacent to Otaiti out to a distance of 1000m. Elevated levels of metals, particularly copper, were also recorded in sediments in the vicinity of the wreckage. There does appear to be some accumulation of contaminants in the food chain although evidence of this is based on only a few samples of kina (sea urchins) and blue cod. Fuel oil contamination was apparent in grazing invertebrates (sea urchins) and in a single fish (blue cod) collected in the vicinity of the wreck.

Further scientific assessment of contamination on Otaiti (Astrolabe Reef) has now been coordinated by the Rena owners through BECA, in collaboration with the University of Waikato, Bay of Plenty Regional Council, Ministry of Primary Industries and Bay of Plenty District Health Board. The results of this survey will provide a more comprehensive understanding of the types of contaminants present on Otaiti as a result of the grounding as well as the magnitude and spread of any contamination. The results of this survey will be published separately and will provide a baseline against which to monitor the recovery of Otaiti. Continued removal of the remains of the wreck and related debris would help ameliorate this contamination and accumulation of contaminants in the food chain.

Introduction

Rena Grounding and Oil Spill Response by Bay of Plenty Research Providers, Te Māuri Moana

Background CV Rena Grounding, Spill and Environmental Consequences

The Rena grounded at 2:20am on the 5th of October 2011. Later that morning a meeting was held by the tertiary partnership (University of Waikato, Bay of Plenty Polytechnic and Te Whare Wānanga o Awanuiārangi) to review what response may be needed to the incident. By the 6th of October the research team had engaged with Maritime New Zealand and forged a field team to review the habitats of the Bay of Plenty, particularly those in the immediate 'line of fire' of any ship contamination (oil or debris) given predicted weather. Engagement with the Bay of Plenty Regional Council (BOPRC) was immediate and drew on their 20+ year environmental datasets and planning documents. There was iwi representation, substantially backed up in the days that followed, particularly from the Tauranga Moana Iwi (Manaaki Taha Moana) and Maketū Iwi (Ngāti Makino). This was a Type 1 marine incident response; that is, an assessment of the immediate environmental risk/impact. To quantify a 'pre-Rena' environmental condition against which any change and recovery could be monitored, it included elements of examining the background ecosystem condition of areas that had been deemed not to have had much previous research (especially the nearshore islands and reefs). Thus, a 'time zero' or background 'pre-Rena' dataset was created for petrochemical and metals chemistry of key species across the full range of habitats (inner estuaries to offshore Islands), and quantitative information was provided on the habitat character and demography of key species. In short order, wider collaborative effort was engaged specifically with the University of Canterbury, to take advantage of their ongoing research based around Mauāo (Mount Maunganui) where permanent rocky reef quadrats had been established, providing a unique opportunity to compare any oiling effects against a backdrop of a 10+ year dataset. In addition, advice was sought from the Great Barrier Reef Marine Park Authority and the Australian Institute of Marine Science, whose expert staff had in recent times been associated with several ship grounding incidents (MV Pacific Adventurer, Bunga Teratai and Shen Neng 1).

Quantitative data from long-term monitoring programmes (20+yrs) from the Bay of Plenty Regional Council and also University of Waikato and Bay of Plenty Polytechnic research existed for estuaries and open coast beaches from Matakana Island to Ōpōtiki region (the area of immediate concern). Thus, baseline data were available before any impacts occurred. This constituted an important and internationally unique situation as it is against this dataset that the degree of impact can be gauged and also the length of time to recovery estimated. However, some habitats close to the Rena did not have 'before impact' quantitative information. These included Mōtītī Island and the rocky reefs adjacent (north and south) to Otaiti (Astrolabe Reef). A fast response survey team was therefore deployed over the three days following the initial grounding (Bay of Plenty Polytechnic and University of Waikato) to retrieve quantitative information on representative rocky reef habitat character, biodiversity and abundances of key species (including kai moana). Samples were collected to attain background hydrocarbon and heavy metal concentrations in sediments, together with fish and shellfish tissue.

Subsequent to this activity, worsening weather conditions precluded further offshore field work and oil began to hit shores from Matakana Island to Pukehina and particularly around Mōtītī Island. The team during this time was actively involved in planning for immediate and long-term monitoring but also carried out shore-based shellfish monitoring of estuary and open beaches in coordination with the Regional Council. On days that permitted offshore work, additional samples were collected from adjacent rocky reef systems.

On land, senior staff from the partnership attended and presented at all iwi and public meetings (refer Appendix I). In addition, information was disseminated at many focused stakeholders meetings (commercial, tourism industry, environmental). The partnership has been able to resource their complementary assets in terms of skill base, community and commercial linkage as well as being able to harness assets (including purpose-built hydrological and dive support vessels, local field experience, chemistry and microbiology facility). The alliance has been extended to key research providers, such as Hill Laboratories in Hamilton, the Cawthron Institute and others with expertise in marine pollution ecology. In particular, the University of Waikato's collaboration with University of Bremen (INTERCOAST) was harnessed in a timely manner to permit the deployment of the Neridis III, a submersible electromagnetic profiling sled that can map the presence of metals over large areas of the seafloor. Neridis III was used to survey extensive regions of the subtidal coastline with the purpose of locating contamination emanating from the Rena.

Research Provision

From the first day of the Rena incident, there was strong call from the public and directly interested iwi, regulatory and commercial stakeholders for detailed and accurate ecotoxicological information. The literature was surprisingly sparse on these resources, with much listed in 'grey literature' or found in the form of single-product material safety data sheets (MSDS). Of particular concern was the lack of information on the possible environmental effects of HFO and mixtures of contaminants likely to emanate from a stricken container ship. Field-relevant information was largely absent. For this reason it was deemed necessary to carry out the appropriate research during the environmental response to Rena using the situation as a rigorous case study. The results of the first phases of this investigation are included in this report as part of the review of environmental effects and recovery. Ongoing research is still underway in the form of a number of MSc research projects at the University of Waikato.

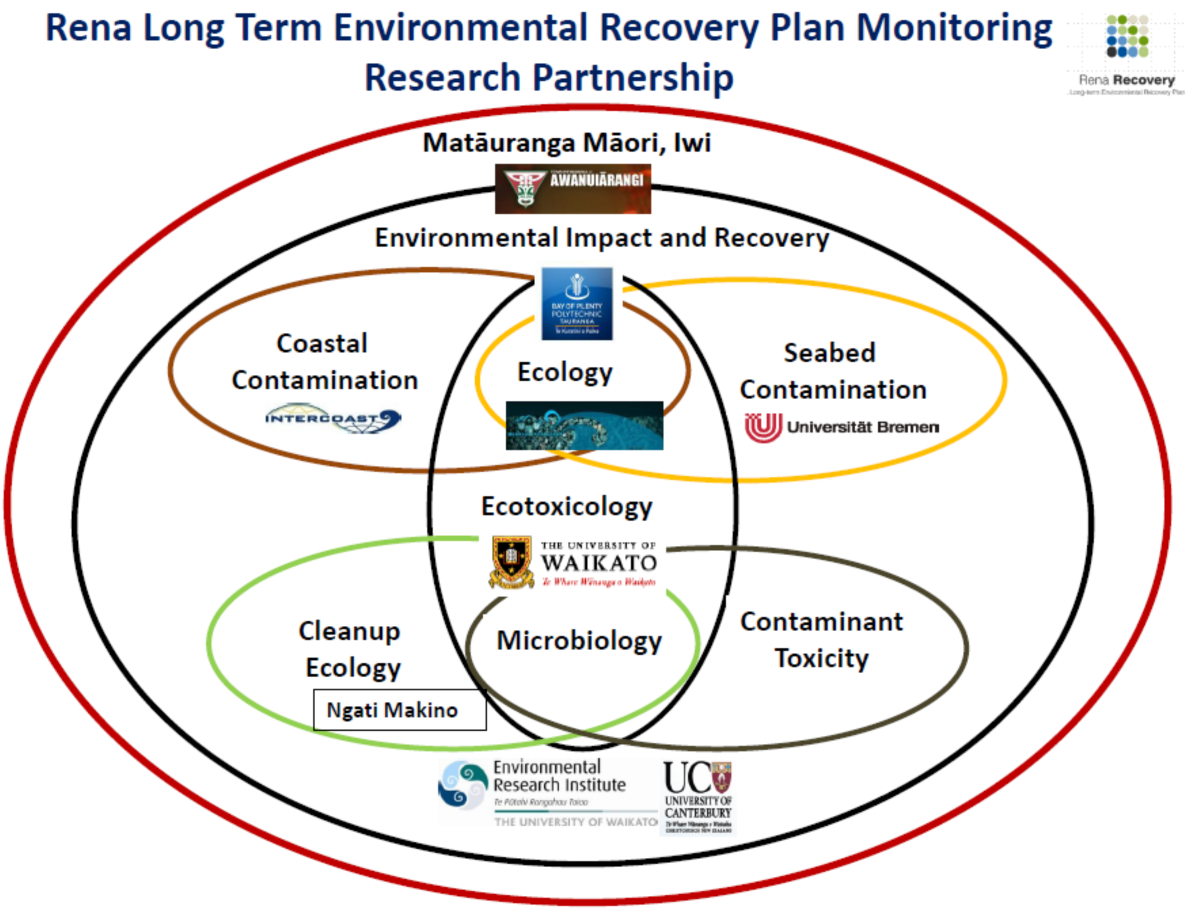
The TMM Rena partnership provides a societal community/regulatory/industry engaged research platform to deliver assessments of:

- Immediate and long-term impact and assessment science
- Water, seafood and sediment chemistry
- Ecohydrology
- Physiological and sublethal impact assessment, oil and dispersant toxicology
- Microbiology and microbial degradation rates

The institutional partnership was originally designed to establish education, training and research stepping- stones of high value to the community, and to improve the regional knowledge economy while internationalising research delivery. The CV Rena grounding necessitated the expansion of this partnership, and it has been shown to be uniquely effective in providing expert response of relevance and engagement with the community while drawing on the best of international advice. Although it was a time of significant environmental crisis, an opportunity existed to provide the best advice on environmental consequences and predictions toward recovery, while at the same time building capacity for the future by training new postgraduate researchers across all disciplines (social and science) and providing much needed New Zealand relevant information on the behaviour of oils, dispersants and other contaminants in marine systems. Of particular importance is the linkage of Mātauranga Māori with Western Science, an underpinning principle of the Te Mauri Moana's engagement.

The Rena Long-Term Environmental Recovery Plan was launched in December 2011, by the Minister for Environment, the Hon. Dr Nick Smith. It is a visionary document in that it bases the need to identify environmental issues associated with the CV Rena's grounding in terms of the mauri of Moana a Toi (Bay of Plenty). The goal of the plan is to "restore the mauri of the affected environment to its pre-Rena state" (RLTERP, Ministry for the Environment 2011). In the spirit of the mission statement, the Te Māuri Moana research team has Mātauranga Māori as a backdrop to all aspects of research. This report provides information toward that goal by identifying the environmental effects of the Rena grounding and loss of oil and container contents, against the backdrop of environmental conditions before the Rena struck Otaiti. It also contains information that will permit prediction of longer term effects and makes recommendations for the next phase of investigation.

Model for integrated research:



Project Summaries

Part 1

The first component of the Rena Long-term Environmental Monitoring Programme is a series of monitoring projects focused on each of the major habitat types present in the Bay of Plenty: open sandy beaches, estuaries, rocky inshore reefs, rocky offshore reefs and islands and the deeper subtidal sand flats. This series of projects provides the backdrop for more focused research work in Part 2. It is envisaged that elements of the monitoring programme will continue.

Project 1a Sandy beach monitoring of oil spill contamination from the Rena

D. Culliford, R. Fairweather; 57pp

To evaluate the ecological impacts of spilled oil and debris from the grounded container vessel Rena on the biota of open coast beaches in the Bay of Plenty, a series of surveys were conducted examining the community structure and abundance of intertidal beach fauna. The primary focus of the survey was the northern tuatua (Paphies subtriangulata). Tuatua are often one of the most abundant infaunal organisms on open coast surf beaches and are an important kai moana species. Here we present a quantitative analysis of tuatua abundance and biomass in relation to levels of oiling, and an analysis of polycyclic aromatic hydrocarbon (PAH) and trace metal contamination. Tuatua abundance and population structure was quantified at 13 locations between winter 2012 and summer 2012/13, with an additional survey in winter 2013 (just completed at the time of report release; preliminary distribution and abundance results included in this report). PAH contamination levels were also compared between the winter and summer periods to establish levels of toxicity and trends in contamination over time. Trace metal contamination was also assessed across the same locations and sampling periods. These values are compared with pre-spill monitoring data.

Analyses indicate that populations of tuatua across Bay of Plenty beaches declined in abundance between the winter and summer sampling periods which generally continued into winter 2013. Average tuatua size was generally smaller at heavily impacted sites. Tuatua populations are known to be highly variable in time and space and as there was no correlation of density of tuatua with the degree of initial oiling on beaches, the observed population dynamics cannot be reliably attributed to the grounding of the CV Rena. Further monitoring of several key sites will reveal whether the observed patterns are part of a natural cycle of variable abundance, or are more likely to be a response to the Rena oil spill. Regardless, biological communities on Bay of Plenty open coast beaches do not appear to have been catastrophically affected by the Rena oil spill. It should also be noted that this project report contains a general introductory discussion of the nature of oil spills, PAHs, and background material pertinent to ecological and ecotoxicological studies.

Project 1b Rocky shore monitoring of contamination from the Rena

D.R. Schiel, P.M. South, S.A. Lilley; 39pp

In the weeks following the 2011 Rena oil spill, a series of surveys was initiated on rocky intertidal reefs to describe the resident ecological communities in the Bay of Plenty, the distribution of oil on rocky shores, and to assess the impacts of oil on those communities. Eight reefs across the Bay of Plenty were sampled on two to four occasions, depending on the site.

A consistent but relatively small cover of oil occurred on two of the eight reef sites (Mt Maunganui and Moturiki/Leisure Island). Intensive monitoring at these two sites made it possible to follow the number and sizes of oil patches at different shore heights and examine the consequences of the oil on intertidal organisms and communities. There was more oil in the high tidal zone compared to the mid zone at both sites and the oil settled mostly on bare rock. The area covered by oil decreased through time and after five months nearly 90 percent of the oil was gone due to natural weathering processes.

There were immediate effects of oil fouling on the little black mussel Limnoperna pulex (which forms a band in the mid intertidal zone) and its associated fauna, with a reduction in the number of mussels and the number of taxa and individuals living within the mussel bed. However, no ecological effects on any of the communities were detectable after one month. Natural disturbances, especially storm events between March and June 2012, had a far greater effect on the cover of mussels and the composition of communities than the oil spill on these reefs. The natural variation in community composition encountered between study sites was in accordance with other studies from across New Zealand, and is likely to be driven by site-specific characteristics (e.g. topography, aspect and wave exposure), and cannot be attributed to the effects of oil.

Our results show that the overall ecological effects of the CV Rena oil spill on the rocky shore intertidal communities were minimal and not long-lasting, but stress that this does not incorporate potential sublethal effects and their consequences on organisms (see other parts of this report). Our work highlights the importance of structured quantitative monitoring in understanding oil spill effects as well as the need for quick surveys before oil hits shore (if possible) and immediately afterwards, to provide a baseline against which to gauge longer lasting impacts. It should also be noted that, for a variety of reasons, Mōtītī Island and the rocky beach front at Maketū were not studied.

Project 1c Subtidal beach and estuary monitoring of oil spill contamination from the Rena

C. Taiapa, L. Hale; 22pp

This report focuses on the impacts of spilled Rena fuel oil in Tauranga Harbour. Specifically, we document polycyclic aromatic hydrocarbon (PAH) concentrations in the flesh of the commonly harvested and ecologically important shellfish species ten months after the grounding of the Rena. The species examined were pipi (Paphies australis), tuangi/cockles (Austrovenus stuchburyi), and the common harbour whelk (Cominella glandiformis), which feeds on bivalve shellfish such as tuangi. Population size structure is also documented for pipi and tuangi at locations where they are commonly harvested and comparisons made between summer 2011–2012 and 2012–2013.

The highest total PAH concentrations recorded for pipi were at site 7 off Fergusson Park (10.7 mg/kg d.w.), while the highest PAH concentrations recorded for tuangi were from a neighbouring site off Kulim Park, Site 2 (23.7 mg/kg d.w.). Elevated PAH concentrations were also detected in whelks (10.5 mg/kg d.w.) again at Site 2. The three PAH variants most commonly found in shellfish within the harbour were phenanthrene, pyrene and fluoranthene. These PAHs are not in the group of seven PAHs that are most likely to be carcinogenic. Pipi and tuangi population size structure varied between 2011–2012 and 2012–2013 sampling events. The causes of the observed fluctuations in size frequency are unknown and are unlikely to be related to the Rena. Further studies will be required to determine whether the variation is Rena-related or a consequence of other temporally variable biotic and abiotic influences, which were not accounted for in this study.

Project 1d Rocky reef monitoring of oil spill contamination from the Rena

K. Gregor, K. Young; 56pp

The offshore rocky subtidal reef surveys provide a snapshot in time of the character of benthic communities in the Bay of Plenty. They were established to capture any major ecological changes in the event of a catastrophic loss of oil from the Rena. While obvious responses to the oil spill were not apparent, there were many localised changes that were statistically significant within sites. These were mainly in the variation in abundance of Ecklonia and other brown algae. At some sites there was a decrease and then increase in Ecklonia which may reflect some temporary impact or recruitment dynamics. Kina (sea urchin) populations appeared to be either less affected by the oiling event or to exhibit lower levels of natural variability relative to other measured taxa. Total abundance of kina and kina size patterns were variable within sites, among sites and among sites grouped by oil proximity. However, few differences among sampling periods within sites were significantly different for both total abundance and kina sizes in both depth bands sampled. In the Bay of Plenty the main predators of kina are adult fish and crayfish. Little is currently known about the longer term effects of reduction of predators as a consequence of oil or other contaminants on local populations.

Catastrophic or highly significant changes associated with Rena impacts would have been picked up by this monitoring regime, however. The lack of obvious shifts in community structure suggests the impacts of the Rena on the monitored locations, with the exception of Astrolabe, are at most, subtle. PAHs and heavy metal contamination of reef fish and invertebrate species were highly variable and not generally found to be above background levels. The effects of contaminants on subtidal rocky reefs of Otaiti in close proximity to the stricken vessel were more substantial and thus are addressed in a separate report and ongoing work (also refer to Projects 1e, 1f).

Project 1e Subtidal reef flat monitoring of oil spill contamination from the Rena

P. Ross, C. Battershill, 41pp

This project reports the results of a brief preliminary and limited-in-scope survey at Otaiti (Astrolabe Reef) carried out in late 2012, together with a broader survey of surrounding seafloor environments. Further work is being done at Otaiti and other islands. The available data demonstrate that Otaiti Reef and associated fauna have been impacted by the Rena event and have to some degree been contaminated by the various substances discharged from the ship into the surrounding environment. PAHs and metals have been detected at above what would be considered natural levels in sediments and reef fauna. Specifically, elevated levels of PAHs and/or metals were recorded in sediments in the vicinity of the wreckage of the ship, in sea urchins and in a single blue cod. However, with the data currently available, it is not possible to properly assess either the magnitude of the contamination or its extent across Otaiti Reef and beyond. Further sampling and analysis will be required to make this assessment.

Polycylic aromatic hydrocarbon levels in sediments and fauna collected from subtidal reef flats off Mōtītī were similar to the PAH levels recorded at the control sampling locations. This result suggests that the effects of Rena-related contaminants on marine flora and fauna are much less at Mōtītī than at Otaiti Reef. However, due to the small number of samples collected and analysed at Mōtītī and the degree of variability in the data it is difficult to be confident of any assessment of the magnitude of contamination at this or other locations. Again, further sampling will be required to properly assess presence or absence of significant contamination on and adjacent to Mōtītī Island and this is currently being carried out.

Comprehensive scientific assessment of contamination on Otaiti (Astrolabe Reef) has been commissioned by the Rena owners and BECA, in collaboration with the University of Waikato, Bay of Plenty Regional Council, Ministry of Primary Industries and Bay of Plenty District Health Board. The results of this survey will be published separately.

Project 1f Chemistry

46pp, together with a separate volume of Appendices

Chem 1: GC-MS Fingerprint Comparison of Rena Oil and some October–November 2011 and January–February 2012 Oiled Sand and Tarball Samples

A. Wilkins

To assess any effects of CV Rena heavy fuel oil specifically, it was necessary to characterise (fingerprint) the oil and its degradation products, especially the formation of tarballs as oil weathers in seawater. The tarballs in beached samples of October 2011 were found to be characteristic of Rena origin following weathering at sea and possible interaction with sediments. The quantified weathering pattern can therefore be used to determine if subsequent tarball contamination incidents are of Rena origin or otherwise.

Tarball Characteristics

The dominant extractable/soluble components of tarballs derived from bunker oils of the type used by the Rena, are straight and branched chain hydrocarbons (alkanes), polycyclic aromatic hydrocarbons (PAHs) and alkylated analogues of PAHs. Low levels of petroleum biomarker compounds such as C27-C35 hopanoids are also detectable in tarballs derived from bunker oil. The origin and significance of hopanoid biomarker compounds is reviewed in Appendix 8.

The extent to which evaporable lower molecular weight hydrocarbons (alkanes) and dicyclic naphthalenes and, to a lesser extent tricyclic PAHs such as anthracenes, phenanthrenes and dibenzothiophenes, are found in tarballs is influenced by the weathering and degradative regimes the source bunker oil and tarballs have been subjected to over time.

Tetracyclic (e.g. pyrenes, benz[a]anthracenes and chrysenes), pentacyclic and hexacyclic PAHs and hopanoid biomarker compounds are resistant to loss by weathering.

Hydrocarbon Profiles

The three Rena tank oil samples generated SIM GC-MS m/z 57 ($C_4H_9^+$) ion profiles which were dominated by straight and branched chain hydrocarbons (possessing 9-20 carbons atoms), together with lesser levels of higher chain length hydrocarbons (possessing 21 to 40+ carbon atoms). SIM GC-MS hydrocarbon (m/z 57) fingerprints of the 18 examined tarball and oiled sand samples varied greatly (see Appendix 1, Project 1f-1). The October 2011 Pāpāmoa tarball samples afforded m/z 57, profiles which were indicative of the loss of lower molecular weight hydrocarbons (up to C15) primarily by evaporation to the atmosphere. However, some of the January-February 2012 and August-October 2012 tarball/oiled sand samples were hydrocarbon-depleted to a much greater extent than can be ascribed to evaporative loss to the atmosphere alone.

PAH, Dibenzothiophene and Tribenzothiophene Profiles

Significant variability was apparent in the extent to which lower molecular weight PAHs such as naphthalene, methylnaphthalenes and dimethylnaphthalenes, and to a lesser extent phenanthrene and dibenzothiophene were retained in the examined tarball and oiled sand samples.

There was a remarkable consistency in the fingerprint patterns and ratio of peaks observed for parent and alkylated phenanthrenes, alkylated dibenzothiophenes, tetracyclic, pentacylic, and hexacyclic PAHs such as fluoranthrene, pyrene, chrysene, benzo[a]anthracene, di- and trribenzothiophenes and C27-C35 hopanoid petroleum biomarker compounds.

Chem 2: SIM GC-MS Comparison of a Rena Tank Oil, an October 2011 Tarball and Four October 2012 Tarball and Oiled Sand Samples

A. Wilkins

The levels and ratios of hopanoids and tricyclic, tetracyclic and higher PAHs, as revealed by the SIM GC-MS fingerprint analyses, are consistent with the proposal that the samples of tarballs and oiled sand from 2/10/2012 and 26/10/2012 are derived from weathered Rena-characteristic bunker oil.

The extent to which hydrocarbons (alkanes) are depleted in the samples of 2 October 2012 (TMMR02528 and TMMR02529) and 26 October 2012 (TMMR00970 and TMMR00971) is greater than can be ascribed to loss by evaporation to the atmosphere alone. It is not known if tidal washing and/or biodegradation may have contributed to hydrocarbon depletion.

The array of dibenzothiophene, methyl dibenzothiophene, tribenzothiophene and methyl tribenzothiophene peaks found in the four October 2012 tarball and oiled sand samples is comparable to those found in the Rena tank oil sample, the October 2011 Pāpāmoa Beach tarball sample and other previously analysed samples of coastal tarballs (October–November 2011 and January–February 2012; see Chemistry Report Project 1f-1).

Chem 3: SIM GC-MS Characterization of Polyaromatic Hydrocarbons (PAHs) in May-August 2012 Coastal Tuatua

A. Wilkins

The highest levels of total PAHs reported by Hill Laboratories for the freeze-dried May–August (winter) 2012 tuatua extracts were in the range of 56–43 µg/kg for four Pāpāmoa samples and a single Leisure Island sample. Levels in the range of 37–35 µg/kg were found in another two Pāpāmoa samples and a Waihī (Bowentown) sample (see Appendix 1, Project 1f-3). All other freeze-dried tuatua samples were found to contain < 30 µg/kg of total PAHs. As of August 2012, these levels were returning to background concentrations. Freeze-dried extracts of tuatua gathered from Waihau Bay and Whangaparaoa Bay showed the presence of low but detectable levels of a selection of total PAHs in the range of 6–17 µg/kg. Although these sites are > 100 km from the Otaiti Reef, they are documented as being impacted by debris, containers and oil after the grounding incident.

The highest level (29.2 µg/kg) of the seven health-risk PAHs was found in the 21 June 2012 Pāpāmoa Domain tuatua extract. Levels in the range of 15–23 µg/kg were found in four other Pāpāmoa Domain tuatua extracts and a Leisure Island tuatua extract. The SIM GC-MS profiles determined for parent and alkylated PAHs present in freeze-dried Leisure Island tuatua extracts and a Rena tank oil sample were compared. Phenanthrene and alkylated phenanthrene, fluoranthene, pyrene, alkylated fluoranthene and alkylated pyrene, benz[a]anthracene, chrysene, alkylated benz[a]anthracene and alkylated chrysene, tribenzothiophene, alkylated tribenzothiophene and pentacyclic PAH and alkylated pentacyclic PAH profiles are consistent with Rena oil origin. The SIM mode phenanthrene and alkylated phenanthrene profiles of 30 of the tuatua extracts and three replicate Rena tank oil profiles were compared. The sensitivity of the SIM GC-MS procedure was such that it was possible to demonstrate the presence of phenanthrene in one of the Leisure Island extracts and five of the Ōmanu extracts at a level below the detection limit of Hill Laboratories PAH method. In all cases, the phenanthrene and alkylated phenanthrene profiles are consistent with the proposal that exposure to bunker oil of the type used on the Rena has contributed to the residual phenanthrene and alkylated phenanthrene levels detected in the freeze-dried extracts.

Chem 4: Polyaromatic Hydrocarbons (PAHs) in May–August 2012 Coastal Kina

A. Wilkins

The objective of the SIM GC-MS fingerprint analyses was to ascertain the extent to which it might be possible to identify PAH and alkylated PAH contributions attributable to Rena-type bunker oil in kai moana species (specifically kina).

Significant levels of tricyclic and tetracyclic PAHs such as phenanthrene, pyrene and chrysene (178, 202 and 228 Daltons) are often present in extract of biota that have been exposed to bunker oils. Lower molecular weight PAHs (naphthalene to fluorene: 128 to 166 Daltons), although more prevalent in bunker oils than higher molecular weight PAHs, are typically not major constituents of biota extracts.

May–August 2012 kina samples

The highest level of total PAHs reported by Hill Laboratories for the freeze-dried kina extracts of May–August 2012 was 73.2 µg/kg, in the guts of a Plate Island (Motunau, site 4 deep) kina sample of 10 August 2012.

Levels of PAHs (primarily phenanthrene, fluoranthene and pyrene) in the range of 51-25 µg/kg were found in the freeze-dried guts and/or gonads of ten of the sixteen kina samples (guts and gonad extracts) analysed by Hill Laboratories. Low but detectable levels of PAHs in the range of 5.5–35.9 µg/kg were found in the freeze-dried extracts of the guts and gonads of kina gathered from Waihau Bay (30/8/2012) and Whangaparaoa Bay (29/8/2012). Although these sites are remote (> 100 km) from the Otaiti Reef, they were impacted by debris, containers and oil after the grounding incident. The Bay of Plenty Regional Council has reported that these sites were lightly or very lightly affected by Rena oil and that only very low, near baseline, levels of PAHs were detectable on a wet weight basis in kai moana from these sites.

SIM GC-MS profiles of Mōtītī Island and Whangaparaoa Bay kina samples.

The SIM mode GC-MS fingerprint profiles determined for phenathrene and alkylated phenanthrenes present in a Rena tank oil sample and the freeze-dried gut extracts of five Mōtītī Island and a composite Whangaparaoa Bay kina sample were compared. Rena tank oils are characterized by four major and a fifth minor alkylated phenanthrene peak (m/z 192 ion responses) in the 15.6–16.2 minute region of the profiles. This pattern is replicated in the biota profiles. A more complex series of dialkylated phenanthrene peaks occur in the 17.5–18.2 minute region of the Rena tank oil and the six biota m/z 206 ion (dialkylated phenanthrene) profiles.

The phenanthrene and alkylated phenanthrene fingerprint profiles determined for the five Mōtītī Island and the Whangaparaoa Bay kina gut extracts are consistent with the proposal that exposure to Rena-type bunker oil has contributed to the phenanthrene and alkylated phenanthrenes detected in these extracts.

Health Risk PAHs

Seven of the sixteen PAHs examined, namely benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[a,h]anthracene and indeno(1,2,3,c,d)pyrene have been reported by the US Environmental Protection Agency (EPA) to be probable human carcinogens. The highest level (5.0 µg/kg) of the seven health-risk PAHs was found in the guts of a Plate Island (Motunau, site 4 deep) kina sample (see Appendix 1, Project 1f-4). No Environmental Protection Agency (EPA) health risk PAHs were found in the majority of the gut or gonad extracts.

Chem 5: Polyaromatic Hydrocarbons (PAHs) in Air Dried August and November 2012 Astrolabe Reef sediments

A. Wilkins

18th–23rd August 2012 Otaiti Reef sediment samples

The highest level of total PAHs determined by Hill Laboratories for the fifteen 18-23 August 2012 sediment samples was 27.788 mg/kg (27788 µg/kg) in the sample from Otaiti site 2 deep reef. This is a very high PAH concentration, which is arguably not surprising as the site is adjacent to the Rena wreckage.

The profile of PAHs observed for this sample and other Otaiti reef sediment samples are consistent with them being derived from bunker oil(s) of the type used on the Rena and are comparable with those determined for the impact period (October-November 2011) and aged (February-August 2012) coastal tarball samples (see Chemistry Reports 1 and 2). A characteristic feature of bunker oil-derived tarballs and aged sediment samples is that the loss of the majority of the lower molecular weight PAHs such as naphthalene, acenaphtylene, acenaphthene and fluorene is observed while higher molecular weight tetracyclic, pentacyclic and tetracyclic PAHs such as fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[k]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[a,h]anthracene, indeno(1,2,3-cd)pyrene and benzo[g,h,i]perylene are largely retained. On the other hand, phenathrene levels in ocean floor sediments are typically greater than those found in coastal tarballs (see Chemistry Reports 1 and 2) due to the oil from which ocean floor sediments are derived not being exposed to long-term atmospheric evaporative effects. The highest levels of the seven EPA health risk PAHs (5588 µg/kg, 4675 µg/kg and 4334 µg/kg) were found in the site 2 deep, site 4 shallow and site 5 deep reef sediment samples respectively. Levels of 1540 µg/kg, 1380 µg/kg, 1110 µg/kg, 809 µg/kg and 737 µg/kg were found in the site 4 deep, site 6 shallow, site 6 deep, site 7 shallow and site 7 deep reef sediment samples.

The levels of the seven EPA health risk PAHs detected in the other 18th-23rd August 2012 sediment samples varied from 11-317 µg/kg.

Alkylated PAH contributions

Alkylated PAHs of the type identified in Rena oil samples (see Chemistry Reports 1 and 2) were present in all of the 18-23 August 2012 samples from Otaiti Reef. Representative SIM-GCMS profiles for alkylated phenathrene, fluoranthene, pyrene, chrysene and benzo[a]anthracenes, as detected in the Astrolabe 2 Deep and Astrolabe 4 Shallow sediment samples.

1st November 2012 outer reef sediment samples

The highest level of total PAHs reported by Hill Laboratories for the extracts of the twelve outer reef sediment samples of 1 November 2012 was 0.72 mg/kg (720 µg/kg) in the GS13 sample. Levels of 0.212 mg/kg, 0.112 mg/kg and 0.099 mg/kg (212 µg/kg, 112 µg/kg and 99 µg/kg respectively) were found in the GS14, GS6 and GS7 grab samples, respectively. No PAHs were detected in the GS1, GS3, GS9 and GS15 samples. Caution should be exercised when comparing the reported levels of compounds in sediment samples because the method of collection and specific site selection of the collector can influence which portions of a typically non-homogenous ocean floor or reef sediment zone are gathered and presented for analysis. The levels of the seven EPA health-risk PAHs in the twelve 1 November outer reef sediment samples that had detectable levels of PAHs ranging from 2 to 232 µg/kg in the GS13 sample. In summary the highest levels of Rena-sourced PAHs occurred in close proximity to the ship. Some samples out to 500m+ also had high PAH profiles.

Chem 6: Polyaromatic Hydrocarbons (PAHs) in Freeze Dried August 2012 Otaiti Reef Kina and other Biota

A. Wilkins

Kina PAH levels

The highest level of total PAHs reported by Hill Laboratories for the freeze-dried kina extracts from Otaiti Reef was 24.191 mg/kg (24191 µg/kg) in the kina gut sample of site 3. A much lower level of total PAHs (306 µg/kg) was detected in the gonads of this sample. Lower levels of total PAHs in the range of 0.914–0.416 mg/kg (i.e., 914–416 µg/kg) were detected in the freeze-dried gut extracts at other sites at Otaiti. As was the case for the site 3 shallow samples, much lower total PAH levels in the range of 0.04–0.179 mg/kg (40–179 µg/kg) were present in the gonads of these samples. Total PAH levels of 0.188 mg/kg (188 µg/kg) were found in the freeze-dried gut extracts of the site 4 shallow samples near the wreck. Levels in the range of 0.109–0.151 mg/kg (109–151 µg/kg) were found in extracts of the freeze-dried kai moana at other shallow and deep sites around the wreck. At sites some distance to the ship, less than 0.02 mg/kg (20 µg/kg) of total PAHs were detected in the freeze-dried gut extracts. Significant variability was apparent in the percent contributions of di- and tricyclic PAHs, tetracyclic PAHs and pentacyclic PAHs. In most cases the fluoranthrene/pyrene ratio was > 1.0, whereas it was generally in the range of 0.3–0.8 µg/kg in freeze-dried coastal kina gut extracts and < 0.33 µg/kg in Rena tank oil samples recovered shortly after grounding of the Rena. The highest level (11490 µg/kg) of the seven EPA health risk PAHs was found in the freeze-dried gut extracts of the site 3 shallow kina sample close to the ship. The levels of the seven EPA health risk PAHs detected in freeze-dried kina gut extracts varied from 0–383 µg/kg.

A selection of the reef kina extracts were examined in SIM mode using a 36 ion suite which fingerprinted the presence of di-, tri- and tetracyclic PAHs and alkylated analogues of parent PAHs in the extracts. A diagnostic aspect of the SIM GC-MS profiles of Rena tank oils and coastal tarballs derived from them is the presence four major methyl phenanthrene peaks in the ratio ca 1:1:1:1 with a fifth minor peak interspersed between the second and third eluting peak (see Chemistry Reports 1-4). This pattern of methyl phenanthrene peaks was detected in the majority of reef kina extracts, confirming Rena origin.

Paua, Crayfish and Fish Species

Total PAH levels in the range of 0.0095–0.057 mg/kg (9.5–57.1 µg/kg) were detected in four freeze-dried paua extracts. Total PAH levels in the range of 0.0008–0.0265 mg/kg (0.08–26.5 µg/kg) were detected in a site 7 deep crayfish (0.0126 mg/kg), a site 9 deep dwarf scorpion fish (0.0115 mg/kg), a site 8 shallow leather jacket (0.0363 mg/kg), a site 4 deep red moki (0.0008 mg/kg) and a site 1 sea perch extract (0.0265 mg/kg). A much higher level of total PAHs (0.265 mg/kg; 26.5 µg/kg) was detected in a site 3 shallow blue cod muscle/liver sample suggesting some food web accumulation. The array and level of PAHs found in the muscle/liver extract are consistent with their source being a Rena-type bunker oil. SIM GC-MS analyses demonstrated the presence in the four paua extracts and the blue cod muscle/liver extract of phenanthrene and five methyl phenanthrenes in ratios indicative of their origin from bunker oils of the type used on the Rena.

Chem 7: Identification of some Organic Compounds other than PAHs and Hydrocarbons in Astrolabe Reef Sediments

A. Wilkins

To ascertain whether or not GC-MS detectable organic compounds other than hydrocarbons and PAHs were present in Otaiti Reef sediment samples, hand selected subsamples of 13 of the 15 inner reef sediments samples and the 16 outer reef sediment samples for which PAH levels had previously been determined (see Chemistry Report 5), were soaked in dichloromethane; compounds present in the soakings were investigated using total ion chromatogram (TIC) and selected ion mode (SIM) GC-MS methods.

The TIC profile of inner reef deep sediment samples was dominated by low-to-intermediate molecular weight hydrocarbon peaks (C10-C20), together with lower levels of an interspersed series of PAH and alkylated PAHs and peaks attributable to some compounds other than HFO. Hill Laboratories reported a total level of 27.788 mg/kg (27788 µg/kg) of PAHs in these sediment samples. The TIC profiles determined for shallow inner reef sediment samples were dominated by peaks also attributable to compounds other than hydrocarbons or PAHs. Hill Laboratories have reported total PAH levels of 12.817, 1.136 and 0.72 mg/kg (12817, 1136 and 720 µg/kg) respectively in these sediment samples. Four groups or series of the compounds, in addition to PAHs and hydrocarbons of the type present in bunker oils of the type used on the Rena, were identified in the TIC profiles of some of the examined reef sediments, namely:

- tributyltin chloride (TBT)
- sulphur (S8)
- a series of compounds believed to be dimeric and trimeric cumene (cumyl) and a dicumyl-phenol analogues
- a series of tricresylphosphate (TCP) isomers.

Although it is likely that sulphur (S8) is a natural background compound, this is not likely to be the case for TBT, TCP and cumyl-type compounds. TBT is a well-known constituent of anti-fouling marine paints. TBT's environmental impacts are well-documented. In recent years its use has been prohibited in many countries.

Little is known about the source(s) and environmental impact of dimeric and trimeric cumyl adducts. Possibly they may be paint-sourced components since TIC GC-MS analysis of the hull scrap sample afforded peaks attributable to series of dimeric and trimeric cumyl adducts, including those detected in reef sediment extracts.

Tricresylphosphate is known to be a component of some hydraulic and lubricating oils. Modern production techniques typically afford mixtures of o- and p-cresyl products. Lesser levels of phenyl or methylated cresyl isomers are generally also present in commercial TCP products. SIM GC-MS profiling verified the presence of phenyl and methylated cresyl isomers in an Astrolabe reef sediment extract. The environmental and human health impacts of m-cresyl isomers are greater than those of o- or p-cresyl isomers.

Detection of TBT, S_8 and TCP in Astrolabe reef sediment samples

TBT, S8 and TCP isomers were detected in all inner reef (August 2012) sediment samples examined in the investigation.

Detection of cumyl analogues in Astrolabe reef sediment samples

The dicumyl adduct compounds, believed to be 1,1,3-trimethyl-3-phenylindane, 2,4-diphenyl-4-methyl-E-pent-2-ene and 2,4-bis(dimethylbenzyl)phenol, were detected in all of the inner reef (August 2012) sediment samples examined in the investigation. Readily detectable levels of the compounds believed to be 1,1,3-trimethyl-3-phenylindane, 2,4-diphenyl-4-methyl-E-but-2-ene and 2,4-bis(dimethylbenzyl)phenol were present in the outer reef sediment sample. This sample is characterised by the highest level of PAHs (0.720 mg/kg) determined for an outer reef sediment sample (see Chemistry Report 5). Other outer reef sediment samples were either devoid of these compounds or characterised by the presence of only low or trace levels of them.

Chem 8: Examination of some Astrolabe reef biota extracts for tributyltin chloride, cumyl adducts and tricresylphosphate isomers

A. Wilkins

The detection of tributyltin chloride (TBT), dimeric and trimeric cumyl type adducts and tricresylphosphate (TCP) isomers in Otaiti Reef sediments (see Chemistry Report 7) prompted an examination of a selection of reef biota extracts using total ion chromatogram (TIC) and selected ion mode (SIM) GC-MS methods.

Tributyltin chloride

A trace level of a peak that may be attributable to tributyltin chloride was detected in some of the kina extracts, but its identification has not been confirmed. It is recommended that biota TBT levels are determined for samples submitted to Hill Laboratories.

Dimeric cumyl adducts

Dimeric cumyl adducts, believed to be 1,1,3-trimethyl-3-phenylindane, 2,4-diphenyl-4-methyl-pent-1-ene and 2,4-diphenyl-4-methyl-E-pent-2-ene, together with 2,4-bis(dimethylbenzyl)phenol were detected in most of the examined biota samples. The NIST library mass spectra of 1,1,3-trimethyl-3-phenylindane and 2,4-diphenyl-4-methyl-E-pent-2-ene are characterized by strong m/z 236 (M+) ions while only a weak M+ ion is seen in the mass spectrum of 2,4-diphenyl-4-methyl-pent-1-ene. Strong m/z 143 fragment ions appear in the mass spectra of 1,1,3-trimethyl-3-phenylindane and 2,4-diphenyl-4-methyl-E-pent-2-ene while a strong m/z 119 ion fragment ion appears in the mass spectrum of 2,4-diphenyl-4-methyl-pent-1-ene. These characteristics are apparent in the m/z 234, 119 and 143 ion profiles determined for peaks observed in the TMMR02533 site 2 kina gut extract.

Dimethylbenzylphenol (= dicumylphenol) compounds

2,4-bis(dimethylbenzyl)phenol was detected in 11 of the 12 examined biota extracts, including the highly contaminated kina gut extract. This compound has hitherto been detected in extracts of inner Otaiti Reef samples; two outer reef sediment samples and a hull scrap sample (see Chemistry Report 7). Since 2,4,6-tris(dimethylbenzyl)phenol, the trisubstituted analogue of 2,4-bis(dimethyl-benzyl)phenol was detected in the TIC GC-MS profiles of some reef sediment samples, it was of interest to determine whether or not it was present in biota extracts. Only a trace a level of 2,4,6-tris(dimethylbenzyl)phenol was detected.

Tricresylphospate isomers
Strong m/z 386 (M+) and m/z 368 (M-H2O)+ ions are exhibited by cholesterol and epimerized cholesterol analogues. Care is required to avoid GC-MS acquisition conditions which lead to the partial overlap of the m/z 368 ion responses of TCP isomers and cholesterol isomers. Tricresylphosphate (TCP) isomers were detected only in the one kina gut and site 1 blue cod muscle/liver sample. The ratio of o,o,o-, o,o,p-, o,p,p- and p,p,p-TCP isomers in extracts of these samples was in accord with that calculated in Report 7, for a 57.3:43.7 ratio of o- to p- isomer contributions, as also found for reef sediment samples.

Results determined for the hull scrap (see Chemistry Report 7) give rise to the hypothesis that the source of the dimeric cumyl adducts and 2,4-bis(dimethylbenzyl)phenol may be paint flakes ingested by grazing biota. Based on the limited information available from this investigation, and from reef sediment profiling, including the signal-to-noise ratio of peaks detected in these investigations, it appears that dimeric cumyl adducts and 2,4-bis(dimethylbenzyl)phenol are more prone to persist in biota than is the case for tricresylphosphate isomers which were only detected in low/trace levels in 2 of the 12 biota samples examined in this investigation. Further analyses of a greater range of biota samples are required to substantiate this hypothesis.

Chem 9: Interim Metals Anaylsis of sediments collected in Winter/Spring 2012 from Otaiti

C. Hendy

Of the sediment samples collected from Otaiti Reef in August and November 2012, 3 samples would exceed international environmental health limits set for lead, 26 would exceed limits set for cadmium, mercury is probably not a problem, between 3 and 6 exceed the limits for copper, 2 exceed the limits for zinc and 18 exceed the limit for aluminium. The samples that were the most contaminated were very close to the wreck.

Project 1g Histology

R. Fairweather, C. Battershill; 13pp

The soft tissue of 48 tuatua from oil-exposed beaches were stained and sectioned, followed by examination under a light microscope to investigate cellular level sublethal effects of Rena oil. The ratio of males to females was not significantly different from the 1:1 ratio expected in tuatua populations and did not vary appreciably across locations be they oiled or control. Consistent variation in goblet cell counts between some locations indicating localised low level irritation in the gill tissue. Some variance in haemocyte and globular cell counts was also observed. However, this variability might be explained by seasonal temperature variation and reproductive condition of the animals sampled rather than being a direct response to oil irritation. Degree of oiling at sampling locations was not a good predictor of these slight cellular aberrations.

The second set of samples (taken from the summer sampling period) had multiple transverse sections of tissue cut on each tuatua tissue sample, whereas the first analyses were only cut longitudinally. Therefore the presence of interstitial haemocytes in the gills and parasitic infection was not noted in the first set. Additionally, the muscle tissue was examined, which again in many cases highlighted the haemocytes and parasitic habitation along with fibrosis in some specimens. This is not uncommon in bivalves and no significant abnormal cellular reaction to their presence was evident. Necrosis was observed in one immature female from Bowentown. Fibrosis in the muscle tissue of another individual from the same site was also noted.

This histological analysis suggests that gonadal and respiratory function has been relatively unaffected by oil in as much as there was no indication of aberrations, even from samples taken from the most heavily oiled beaches. It is recommended, however, that monitoring of reproductive condition continues with any monitoring of population dynamics at control and heavily oiled sites to determine if there are longer term affects.

Project 1h Microbiology

C. Carey; 10pp

The grounding of the CV Rena on Otaiti (Astrolabe) Reef is one of the worst maritime disasters in New Zealand. Understanding the impacts caused by the spill of hydrocarbons and cargo on reefs and beaches is essential to help in the management of similar situations in future. Microbial communities have always been regarded as among the first organisms to respond substantially in any ecosystem to the rapid introduction of contaminants. In this study, sediments collected from different parts of Otaiti Reef were used for microbial community analyses, with their associated PAH values being used as criteria for selecting the appropriate sediment samples for analyses.

Uncontaminated sediment samples (low PAH values), as expected, had their own unique natural community profile. Contaminated sediment samples were in general shown to have greater similarity in their community profiles, suggesting that enrichment from heavy fuel oil contamination or discharge from the grounding of nearby CV Rena was causal. However, these data are not conclusive evidence at this time for any validated correlation between the microbial communities and the PAH values. The sampling that was carried out did not account for local heterogeneity in the microbial communities, was not replicated, nor were time points taken before and after the grounding. Clearly, more research is required on the effects of hydrocarbons and the associated microbial response in New Zealand ecosystems. This could include undertaking controlled and replicated studies determining the shifts associated with the introduction of heavy fuel oil or other more common fuels to follow the impact and recovery over time. This study is currently underway..

Further studies could be done on the existing Otaiti Reef samples using next-generation sequencing to investigate the compositional differences between natural sediments and those enriched with heavy fuel oil or other known Rena contaminants. From the study presented here four samples have been chosen for this approach and are currently in the sequencing pipeline at the University of Waikato. Finally, a common global problem in these unforeseen spills is the obvious lack of understanding of the impacted native ecosystem.

Part 2

These projects are, for the most part, the result of summer and student MSc scholarships that were associated with the Rena Environmental Recovery Programme. Most are continuing and final write-up of these will occur in December 2014 at the completion of the MSc thesis period. Copies of theses will be made available online.

Project 2a Effects of Rena Oil on Micro Algal species

K. Reihana; 32pp

Ultra-trace dilutions of weathered Rena oil (WRO) had a significant positive impact on growth rates of micro-algal species in laboratory experiments. The control growth rates after a 72-hour period had reached their limit and had become exhausted as a culture. This was observed without any additional growth nutrient to aid in stabilising the culture. However, the composition of the WRO is not well-defined and may contain trace amounts of nutrient in some form. As no additional nutrients were added to aid in their growth rates, it can be surmised that in its coarse form WRO aided in the growth rate of the contaminated samples. Further investigation would be required to determine whether a similar impact of WRO would be observed in the field environment. However, anomalies of the environment would also need to be considered in such a study and therefore may not give results which are as clear as in this research. If these results could be calibrated against environmental biomarkers then we could ascertain if WRO may be affecting the marine food web. What kind of effect, and to what extent, would need further investigation.

Project 2b Ecotoxicology

Project 2b-1: Effects of Corexit 9500 and Rena oil to kingfish larvae

S. Muncaster; 12pp

This study aimed to test the effects of the water soluble fraction (WSF) of heavy fuel oil from the Rena and Corexit 9500 on the embryo and larval stages of kingfish. A secondary aim was to develop standardized techniques to assess the toxicological impacts of soluble oil compounds and commercial dispersants on marine organisms. The current results show that short-term exposure of kingfish embryos and larvae to concentrated WSF for up to 24 hours is not immediately lethal. Although the short-term exposure period used in this study did not show immediate evidence of PAH impacts, observations over a 48 hour period indicate that significant organ and structural damage were incurred. Although limited data are available to date, the current study indicates that Corexit 9500 alone may be toxic to both kingfish embryos and larvae, although data are ambiguous when compared to dispersed oil. Observational evidence shows that continuous exposure of 50 percent WSF over a 48 hour period induces classic blue sac disease in kingfish larvae. The extent of these impacts should become more evident following the completion of histological and DNA damage analysis.

Project 2b-2 Ecotoxicology of Rena Oil, Dispersant and Cryolite on Crayfish, Snapper and Wrasses

N. Ling; 13pp

An experimental laboratory study of acute effects of environmentally realistic exposure durations and concentrations was undertaken to examine major pollutants of the Rena shipwreck. This report presents preliminary data from this research project which is ongoing until June 2014. Effects of

Rena heavy fuel oil either singly or in combination with Corexit 9500 dispersant, and aluminium hexafluoroaluminate (Cryolite) were examined in sub-adult spotted wrasse (Notolabrus celidotus), snapper (Pagrus auratus) and red rock lobster (Jasus edwardsii) for periods up to 96 h duration. Analysis of fish bile indicated rapid and significant uptake of PAH compounds from oil, however, uptake did not appear to be enhanced by combined exposure to Corexit 9500. Minor effects of oil and cryolite were observed on some haematological parameters of both spotted wrasse and snapper but may reflect a generalised stress response to toxicant exposure rather than a specific toxicant effect.

Project 2c Oil spill clean-up efficacy at Maketū

T. Gaborit-Haverkort; 21pp

Ōkūrei received patches of light to heavy oiling between Newdicks Beach and the Maketū Surf Club from the 12th to 17th of October 2011. The oil came ashore in patches of differing severity; however, there was a definite band of oiling throughout the splash zone all the way around the point and at the edge of rock pools in the mid tide zone. No oiling was observed on rocks in the low tide zone. This pattern of oiling concurs with previous reports from oil spills on rocky coastlines.

A commercial product, 'SpillSorb', effectively removed fresh oil from all rock types tested at Maketū (grey rhyolite, hydrothermally altered ignimbrite with lenticles and lenticulite ignimbrite), which concurs with previous reports of SpillSorb use on rocky coastlines. The use of SpillSorb to remove surface oil in rock pools was assessed; SpillSorb absorbed the oil sheen from the surface, which concurs with previous tests of the absorption capacity of Canadian peat moss. However, there were concerns that it was difficult to scoop the product off the surface and much of the product remained in the environment. There are numerous reports stating that once SpillSorb absorbs hydrocarbons it does not leach. The disposal of SpillSorb containing hydrocarbons in landfill is also acceptable. Research into the direct application of Spillsorb to oil slicks at sea found that once Spillsorb has absorbed hydrocarbons it floats and does not sink to the sea bed. This would likely result in clumps of non-sticky SpillSorb washing up on shore rather than a layer of oil, resulting in a much easier clean-up operation. However, if the Spillsorb floats on the surface it may be ingested by plankton feeders such as kahawai (Arripis trutta). Whether SpillSorb leaches hydrocarbons when ingested by marine birds, fish and mammals requires further research.

Following a survey of the Maketū coast one year after the Rena grounding and oil spill, three small patches of oil remnants were located in the splash zone. No fresh oil or other remnants were seen. The remnant oil patches looked like they had been cleaned using SpillSorb; it is likely that remnants remain in this area due to the oil being on the top of large rocks at the high tide mark, where wave action rarely reaches. No other remnants were seen, even in the worst hit areas, which may be attributed to the breakdown of hydrocabons by wind, waves, currents, existing oil-degrading bacteria, nutrients, and oxygen.

There is a variety of methods for the treatment of oil spills, all of which rely on human labour. The use of fertilisers and/or seed cultures of oil-degrading bacteria to encourage bioremediation would have been less labour-intensive. However, oil-degrading bacteria occur in all aquatic environments and they reproduce greatly in the presence of oil. It may therefore be useless to add more. In addition, the local population of Maketū would not likely have been able to stand back and wait for the coastline to clean itself; volunteering was therapeutic for people and brought the community closer together. Manually cleaning the rocks using SpillSorb was labour-intensive and exposed volunteers to the oil. However, this method was still preferable to alternatives such as using chemical dispersants and water stripping. In rocky shore environs classical mechanical and chemical procedures for rock cleaning are difficult to control and generate waste and debris that require complementary techniques for their removal. Despite the final clean aspect of the rocks, these methods may cause more environmental damage than fuel oil by itself and are not recommended in contaminated zones that are especially delicate. In New Zealand there is great need for well-controlled, well-replicated, full-scale field tests to find out which clean-up methods would be most useful for various oils, fuels and shoreline types.

Project 2d The mixing of the Rena oil spill into sandy beaches

N. de Groot, W. de Lange; 11pp

Twenty-five sediment cores that were vibrated into beach sediments to a depth of approximately 1 meter were split and visually described. There was no visual presence of oil in any of the cores at any depth. Chemical analysis of the cores has also found no traces of Rena PAHs or their degradation products, apart from one core at Ōmanu which had some oil close to detection levels. The oil had some of the chemistry consistent with Rena origin, but not all. Therefore, it was concluded that there is unlikely to be significant quantities of residual Rena-derived oil in Bay of Plenty beaches. Because of these results, it was decided not to undertake a second round of core sampling.

An alternate investigation into the impact of oil on the sediment characteristics will now form the basis of ongoing work. Various organic compounds were found in some of the cores. For example, an unexpected high abundance of triphenylphosphine sulphide was present in the Ōmanu Beach cores. Further research is required to identify the source.

Project 2e Understanding the role of estuarine-shelf exchange in controlling the hydrodynamic dispersal and mixing of oil

H. Jones, K. Bryan, J. Mullarney, W. De Lange; 38pp

Oil spill dispersal over the month following the Rena grounding was hindcast using a combination of hydrodynamic and oil-dispersal modelling. Tidally-driven currents were modelled on the Bay of Plenty shelf and in Tauranga Harbour using three-dimensional hydrodynamic models Delft3D and ELCOM, respectively. Hydrodynamics were calibrated and verified using observations from the Bay of Plenty Regional Council, the Port of Tauranga and past studies by the University of Waikato. Water level was well-predicted by both models (with a mean absolute error of 0.08 m) and currents were predicted well within the Harbour and less well on the shelf. The modelled currents were used as forcing for the NOAA oil-spill model GNOME, along with observed wind speed and direction collected at the Tauranga Airport meteorological station.

Oil was predicted to reach the shoreline on 13 October (8 days after the grounding), which was consistent with SCAT surveys. Hot spots of oil accumulation occurred on the northwest side of islands and headlands, as the oil dispersed southward along the coast, also consistent with SCAT surveys. Hot spots of oil were predicted along the open coast beaches, but were not very well aligned with observations, which could be because the surf-zone and rip-current circulation was not represented in this implementation of the model. Accumulation of oil was predicted around Mt Maunganui, which was caused by eddies forming on the tidal jet depositing oil onto the headland. Within the Harbour, the highest accumulation of oil was predicted in Pilot Bay, which was caused by the anti-clockwise eddy inside the harbour. These predictions were qualitatively supported by observations from the SCAT surveys.

Model predictions were sensitive to assumptions about the timing and volume of oil released during the grounding, which was difficult to measure with any accuracy. The dispersal of oil (both observed and modelled) is highly dependent on the prevailing wind patterns, and more accurate prediction of oil dispersal and accumulation would require better observations of local wind patterns. Nevertheless, the qualitative comparison of predictions with observations indicated that the GNOME modelling approach was an effective low-cost tool. Moreover, Delft3D and GNOME are both open source and freely available software packages.

Project 2f Dispersal of oil and variable buoyancy debris from the Rena

W. de Lange; 4pp

This project was tightly coupled with Project 2e - Understanding the role of estuarine-shelf exchange in controlling the hydrodynamic dispersal and mixing of oil. The main aim of both projects was to develop coupled hydrodynamic and particle-tracking models that can replicate the observed dispersal of oil and shipping containers from the Rena. Project 2e focussed on the dispersal of oil, while Project 2f was intended to focus on the dispersal of containers. Both projects use the same suite of hydrodynamic and particle tracking numerical models. However, while existing particle tracking models can simulate oil dispersal, they do not cope well with container and debris dispersal. Project 2f is intended to improve our ability to track the dispersal of containers. The project was to be undertaken in two phases: first, the locations of recovered containers were to be compiled, and then related to archived ocean circulation model data; and, second, models will be developed and calibrated with the observations. The immediate purpose of phase one was to identify potential destinations for containers that were still unaccounted for by matching the characteristics of recovered containers with those missing.

Due to the lack of useful data, the dispersal data for containers and debris were not collated into a usable database. However, the location of oil from the Rena recovered by response teams was combined into a geospatial Excel database with the inclusion of information about the characteristics and distribution of the oil across the shoreline. This database was then incorporated into the calibration and verification of the numerical oil dispersal models in project 2e. The database is available as an Excel spreadsheet “SCAT SPREADSHEET DATA.xlsx”.

Project 2g Electromagnetic Profiling the Sea floor for contamination from the Rena

T. Von Dobenek, C. Battershill; 25pp

Detailed data analysis of a very large dataset (over 800,000 high resolution images and many terabytes of electromagnetic and other data) is ongoing at the time of preparing this summary. However, no clear metal contamination attributable to Rena has been seen thus far in the electromagnetic profiles taken. A number of small isolated metallic signals that are assumed to be of anthropogenic origin have been detected, but these are likely to have been an accumulation over many years of shipping traffic (for example, a fork was observed in the photograph of one of the metal items detected, indicating the extremely high resolution of this sampling technique). Furthermore, only one object (a canvas or similar bag) that may or may not have some association with Rena was seen in analysis of over 8,000 images thus far. No indication of plastics or other debris directly identifiable from Rena containers was observed. The bulk of the electromagnetic and photographic work has yet to be returned from the University of Bremen (due to the enormous dataset created), but it would appear that the near shore regions of the Matakana, Mount Maunganui and Pāpāmoa beaches are relatively devoid of any Rena debris contamination at the time of the survey.

Acknowledgements

The authors are indebted to the leadership of Catherine Taylor, the Chair of the Rena Long-Term Environmental Recovery Plan Steering Committee from its inception. Catherine has been tireless in support of this programme and has done everything to facilitate fast and efficient work. She was significantly instrumental in smoothing the pathway for interaction with stakeholders and even in securing supply of HFO for experimental studies.

We are also indebted to the strong support and vision of Rob Donald, the Chief Scientist administering this Programme on behalf of the Bay of Plenty Regional Council. Rob has been unwavering in his practical support and provision of scientific advice in the many times where choices had to be made as multiple pressures for differing components of work to be completed simultaneously needed to be managed. We are indebted also to Bruce Fraser who also has been with the programme from the very beginning and who has managed the final phases of this work. Catherine, Rob and Bruce: you have been fantastic.

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All of the above have given the research team great freedom in pursuing the investigation of the effects and environmental recovery associated with the CV Rena incident. All have supported the ambitious decision to build educational opportunity into the research effort in the form of 15 scholarships that have enabled a new generation of environmental and ecotoxicological researchers to begin their careers. The additional work that was possible through this visionary approach is substantial. Special mention needs to be made of Clare Dowthwaite, Millie Freeman and Nyree Sherlock for their enormous effort in ensuring accurate and timely flow of information to the public.

We wish to thank Maritime New Zealand for their comprehensive support and access to information and for facilitating the field programme. In particular, we thank David Billington and Reece Golding. We thank Brett Beamsley of MetOcean Services and Shane Wasik for timely and comprehensive assistance in the early days. Simon Valentine, John Curley, Mike Holloway, Mike Richards, Allan Price, Kerry Snowden and Adam Desmond of Braemar Howells, Unimar and Resolve all facilitated safe access to the Rena when required.

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To achieve the goal of providing scientific information based on engagement with Mātauranga Māori and deliver it in a form that was relevant and useful to achieve the ultimate aim of assessing the state of the mauri of the environment, we are indebted to numerous people, hapū and iwi. Without very close collaboration and guidance from the following, we would not have achieved this work. We thank Raewyn Bennett; Elaine Tapsell; Rangi Butler; Hamiora Faulkner; Reon Tuaneau; Jack Thatcher; Tuihana Pook, QSM; Betty Dickson; Jason Murray; Rahira Ohia; Matemoana MacDonald; Matire Duncan and Kataraina Belshaw. We are indebted to Carlton Bidois for wide-ranging guidance across the entire programme and to Lee Taingahue for her tireless work in facilitating engagement with iwi leaders across the Moana a Toi. Thanks are also due to Charlie Tawhaio and Joe Harawira from the Iwi Leaders Forum for their guidance and for liaison with the Moana a Toi Iwi Leaders Forum.

We wish to thank the Kaumātua of the Moana a Toi Iwi who have been nothing but supportive of this programme and who have hosted us many times on marae, in particular, Maketū and Mōtītī.

All those in the study express their heartfelt thanks to Pia Bennett, Carlton Bidois and Caine Tiapa whose vision and advice in marrying Mātauranga Māori and western science is benchmarking how such programmes can be put together.

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The authors acknowledge and thank the many volunteers who sieved mud, diligently traversed the beaches in the coldest months of the year and who have largely gone unnoticed and unacknowledged in their pursuit of the science associated in understanding how the environment has fared following the Rena grounding. These people are acknowledged specifically in each Project report, but they are deserving of much credit as they have been selfless in their dedication to the Programme.

Finally, the authors wish to gratefully acknowledge the community of the Bay of Plenty. It has been heart-warming to experience their support, care for their environment, willingness to help and their continued interest in this ongoing story. In many ways, the oil spill and its aftermath have brought the community closer together in pursuing common goals relating to the precious sea environment that we all share. Kia ora.

Appendix I

Timeline of Major Events for the TMM RLTEMP to June 30 2013

(incorporating elements from Maritime New Zealand & Rena Recovery)

5 October 2011	**The 37000 tonne cargo ship CV Rena hit Otaiiti (Astrolabe) Reef at 2:20am. On board were 1760 tonnes HFO; 200 tonnes marine diesel, 1368 containers**. By 7am, Maritime New Zealand had declared a tier 3 emergency, the highest level of response to an oil spill, and mobilised the National Response Team for oil spill response. Maritime New Zealand also activated its Maritime Incident Response Team to monitor and respond to the situation.
6 October	A small amount of oil was found to have leaked overnight prompting aerial deployment of oil dispersant**. Environmental monitoring survey team deployed to provide a 'pre-Rena' fast response environmental assessment.**
9 October	Salvors began removing the estimated 1,350 tonnes of oil in various tanks on Rena but were hampered by bad weather, equipment breakdown and hazardous and changeable conditions. **Environmental stakeholders assessed response options.**
10 October	**Oil discovered on Mt Maunganui beach. Clean-up teams commenced collecting oil from beaches.**
11 October	**Storm overnight resulted in loss of an estimated 350 tonnes of oil from Rena (Maritime NZ).** **5 km slick surrounded Rena. Oil washed up at various points along Bay of Plenty coastline.**
12 October	**Approximately 30 containers fell into the sea. Beaches closed from Mt Maunganui to Maketū. A significant amount of oil washed up on Pāpāmoa Beach.**
13 October	Ship on 20° list, **88 containers lost overboard**, 20 came ashore, and 14 recovered at sea.
14 October	**Rena cracked apart, but held intact on the reef**. More than 220 tonnes of oiled sandy waste collected from the beaches and taken to the transfer station.
22-23 October	**A further 5-10 tonnes of oil lost from vessel overnight**. Oil spill response personnel and volunteers, including large numbers of locals, worked to clean oiled beaches and recover debris from the containers. Wildlife experts from the National Oiled Wildlife Response Team treated oiled birds, including little blue penguins and pied shags, and pre-emptively caught 60 rare New Zealand dotterel to prevent them becoming oiled. (These birds were later re-released back into cleaned environments in a staged release programme.)
15 November	Over 1,300 tonnes of HFO were eventually recovered from Rena, with all accessible oil removed.
16 November	Container removal operations from Rena began once all of the oil had been removed.
December	**Bad weather caused more oil to leak, more debris**. By 26 December, 341 containers removed from Rena.
8 January 2012	Rena separated into two pieces.
10 January 2012	**Stern section sank.** An estimated 200-300 of the approximately 830 remaining containers were lost overboard: at least 49 containers were identified floating in

	the sea, 25 of which washed ashore. Container debris retrieved between Waihī Beach and Maketū comprised mainly plastic beads, milk powder, and some meat products.
24 January	**497 containers processed on shore** - 441 lifted off the wreck and 56 collected at sea or from beaches.
February/March	Coastal clean-up continued.
4 April	**Stern section sank completely in severe weather**.
May	**815 containers retrieved and seabed recovery of debris commenced**.
June	**Accessible containers removed from the submerged stern section** 944 containers have been processed ashore.
July	**Rena owners and representatives met with community groups and leaders**. Collection of container scrap from the seabed surrounding the Rena wreck; 20 containers have now been hoisted from the ocean floor with the number of containers landed and identified: 968.
August	Total number of containers salvaged: 986.
September	High winds and rough seas result in approximately 25m of fore section, weighing around 250 tonnes, being ripped free from the aft portside and falling to the sea bed. Number of containers salvaged: 999.
October	Incident Anniversary. **Public dissemination of the Environmental Recovery Programme results to date.**
November	**Te Mauri Moana Iwi Leaders Forum**.
December	**Full engagement of the second summer monitoring programme, scholarship programme and ecotoxicity studies. First environmental survey of Otaiiti (2 days).**
January 2013	**Summer programme survey repeated and experimental studies commenced.**
April	**End of summer environmental work.**
May	**End of chemistry for the first phase of environmental work.**
June	**New comprehensive review of the environmental health of Otaiiti. Submission of the RLTERP report for independent review.**

Additional winter 2013 monitoring was undertaken to October 2013 and will form an additional report. Immediate ecological results are reported here (chemistry pending).

Invited Public Keynote Addresses to 30 June 2013: Rena Environmental Review

2013	26 June New Zealands Preparedness for an offshore Oil and Gas Industry. Invited Dept of Petroleum and Minerals MBIE.
2012	28 November. Invited Parliamentary Presentation, Wellington: Rena
	27 November. Invited Keynote Geosciences 2012 Conference, Coastal Research
	2 July. NZ/Australia Joint Marine Science Conference, Hobart.
	16 -23 June. Invited Public Seminar, House of Science Bremen Germany.
2011	Māori Council (28 April).

Summary of Hui, Public Meetings and Media as at 30 June 2013

7.10.11	Rena ICC Airport Initial Instructions
8.10.11	Rena - airport, field deployments
9.10.11	Rena and Mōtītī Island briefings, field work
10.10.11	Rena - Waikare Marae Matapihi (Battershill summary of status.
11.10.11	Rena ICC Foodtown Minister Hon Nick Smith briefing (Battershill)
12.10.11	Bay Times Interview (Battershill)
12.10.11	Commercial Operators and Maketū Public Briefings (Taylor, Battershill et al)
12.10.11	Environmental Stakeholders and Radio Breifings (Taylor, Battershill et al)
12.10.11	Marine Stakeholders, Pāpāmoa, Mount Maunganui Public Briefings, Closeup, (Taylor, Battershill et al)
14.10.11	Mount Maunganui Hall Public #2, Regional Councillors, Pāpāmoa #2 breifings, ICC Survey design briefing, Whareora Marae Bridge Meeting (Taylor, Battershill et al)
15.10.11	Pāpāmoa briefing #3, TV1, Radio Live interviews, Commercial Stakeholders update, Waihī Beach Public briefing (Taylor, Battershill, Schiel et al)
16.10.11	ICC briefings
17.10.11	Whakatāne Community Briefings, Hui Mataatua Marae, Te Manuka, Tutahi, Whakatāne (Taylor and Battershill)
18.10.11	First Line interview, Hon Wayne Mapp briefing, Tauranga wildlife rescue centre
19.10.11	Pukehina Hall briefing
26.10.11	Tertiary Partnership Project briefing Te Mauri Moana (Pāpāmoa), Katikati RSA briefing
30.10.11	Hui Te Kaha, Bay of Plenty Regional Council briefing
3.11.11	Hui and monitoring design workshop iwi impacts.
9.11.11	Monitoring design workshop for Bay of Plenty Regional Council
10.11.11	Te Mauri Moana workshop, update and planning
1.11.11	Māori Council, Tauranga Hui, briefing
13.11.11	Oceanz Conference, Marine Debate Panel, Tauranga (Battershill, Bridges, Dalzeal, Edwards)
14.11.11	Marlin Porbus Seminar and briefing
17.11.11	MAF Biosecurity briefing
21.11.11	Café Scientifique –Tauranga
22.11.11	Cafe Scientifique – Hamilton
30.11.11	Workshops hosting Prof Russ Riechelt CEO GBRMPA and Board Member AMSA
5.12.11	Briefing Mōtītī Is Marae
6.12.11	Briefing Whakatane, Joe Harawira
7.12.11	Rena discussed at opening of Marine Station, Tauranga
16.12.11	Environmental Recovery Givernance Group meeting; Launch of the RLTERP
20.1.12	Coastal Economic Symposium, Tauranga
26.1.12	Environmental Recovery Governance Group meeting
7.2.12	Mōtītī Island Marae briefing
2.3.12	Rena volunteer research presented at Inquire Inspire Symposium, Tauranga
3.3.12	Marine Station Open Day/SeaWeek, Tauranga
7.3.12	Tauranga Harbour Recreational Users Briefing
2.4.12	Café Scientifique – Pim de Monchy discussed Rena volunteer response, Tauranga

12.4.12	Te Mauri Moana Workshop
18.4.12	Mōtītī Is Marae workshop
2.5.12	Iwi Liaison meeting
10.5.12	Manaaki Taha Moana and Matakana Is Iwi briefing
11.5.12	Open Day Talk, Seaweek at the Coastal Field Centre
15.5.12	Lions AGM Waihī Beach seminar
16.5.12	Kingitanga Day – Panel discussed Rena experience for iwi, Hamilton Campus
24.5.12	Panel discussion Pāpāmoa Domain Hall (Hon J Key et al).
29.5.12	Maketū Briefing
6.6.12	Radio NZ Interview, TV1 Interview
7.6.12	Waikato Times Interview
8/9.6.12	Radio NZ Documentary Alison Ballance
27.6.12	Mōtītī Is Powhiri
28.6.12	Hui Ngaiterangi Board Room
18.7.12	Manaaki Taha Moana workshop
25.7.12	Chemistry review University of Waikato
27/28.7.12	Future Focus Showcase – University of Waikato Rena work displayed, Tauranga
1.8.12	Steering Group Meeting
3.8.12	Microbiology review University of Waikato
22.8.12	Northern Harbour Recreational Users Forum Katikati RSA Briefing
28.8.12	Te Kaha Powhiri
4.9.12	Rena Governance Group meeting
12.9.12	Sunday Star Times Interview
13.9.12	Pāpāmoa Iwi and Mauao briefings Pāpāmoa
5.10.12	Media briefing Mount Fire Station (MNZ HQ)
10.10.12	Rena Anniversary workshop
11.10.12	Rena public briefings, "One Year On", organised by Rena Recovery team, Tauranga
16.10.12	Steering group meeting
23.10.12	Bay of Plenty Regional Council Council Formal Update (Whakatane)
25.10.12	Transitional Arrangements
29.10.12	Meeting Salvors and University of Bremen for Electromagnetic profiling
31.10.12	Rena discussed at opening of Marine Station extended premises, Tauranga
5.11.12	Rena Owners Briefings
6.11.12	RLTERP Project Leaders meeting
19.11.12	Matauranga Māori Maketū Workshop
27.11.12	Invited Lecture Rena to 2012 Geosciences Conference, Hamilton Campus
28.11.12	Invited Lecture Speakers Forum Parliament
11.12.12	Steering Group meeting
19.1.13	Otaiiti Review Iwi leaders forum
25.1.13	Scholarship students presented Rena research at Coastal Economic Symposium, Tauranga
7.2.13	Pāpāmoa Rotary Briefing
8.2.13	Chemistry review, University of Waikato
15.2.13	BECA Update
7.3.13	Rena displays at BAY OF PLENTY REGIONAL COUNCIL Harbour Symposium, Tauranga
9.3.13	Rena displays at Marine Station Open Day/SeaWeek, Tauranga

14.3.13 Workshop to confirm Otaiiti sampling design BECA
25.3.13 Café Scientifique – Battershill discussed coastal research in BOP including Rena, Tauranga
24.4.13 Te Mauri Moana Project Leaders science review workshop Tauranga
7.5.13 Steering Committee briefing
13.5.13 Ngahere Toa Hui
15.5.13 Rena Steering Committee report to Bay of Plenty Regional Council, and TMM project update Whakatane
21.5.13 Lions AGM Waihī Rena briefing
26.6.13 Invited seminar Dept Oil and Gas and Minerals MBIE, Rena update
30 June 2103 Submission of Final Drafts Te Mauri Moana RLTERP reports.

Media examples to June 2013:

14.10.11 University of Waikato heavily involved in Rena response http://www.waikato.ac.nz/news-events/media/2011/10university-of-waikato-heavily-involved-in-rena-response.shtml

25.10.11 Detailed picture of Rena oil emerging thanks to University of Waikato scientists http://www.waikato.ac.nz/news-events/media/2011/10detailed-picture-of-rena-oil-emerging-thanks-to-university-of-waikato-scientists.shtml

7.11.11 Rena environmental impacts to be discussed at Tauranga Café http://www.waikato.ac.nz/news-events/media/2011/11rena-environmental-impacts-to-be-discussed-at-tauranga-cafe-scientifique.shtml

8.11.11 Waikato scientists to discuss Rena oil spill at two Café Scientifiques http://www.waikato.ac.nz/news-events/media/2011/11waikato-scientists-to-discuss-rena-oil-spill-at-caf%C3%A9-scientifiques.shtml

18.11.11 Waikato oceanographer says Rena oil best washed up on beaches http://www.waikato.ac.nz/news-events/media/2011/11waikato-oceanographer-says-rena-oil-best-washed-up-on-beaches.shtml

21.11.11 Waikato University student studying kai moana recovery in wake of Rena http://www.waikato.ac.nz/news-events/media/2011/11kaimoana-recovery-examined-posted-rena-spill.shtml

22.11.11 Ongoing research into Rena impacts critical to environmental recovery http://www.waikato.ac.nz/news-events/media/2011/11ongoing-research-into-rena-impacts-critical-to-recovery.shtml

24.11.11 Effect of Rena dispersants to be known by Christmas – Waikato Professor [not sure if this was sent to media as it doesn't appear on University of Waikato website]

8.12.11 University of Waikato opens new coastal research field station http://www.waikato.ac.nz/news-events/media/2011/12university-of-waikato-opens-new-coastal-research-field-station.shtml

13.12.11 University brings together scientists for coastal forum http://www.waikato.ac.nz/news-events/media/2011/12university-brings-together-scientists-for-coastal-forum.shtml

14.12.11 Students, staff get stuck into Tauranga harbour study http://www.waikato.ac.nz/news-events/media/2011/12students-and-staff-get-stuck-into-tauranga-harbour-study.shtml

24.2.12 University celebrates Sea Week with Marine Station open day http://www.waikato.ac.nz/news-events/media/2012/02university-celebrates-sea-week-with-marine-station-open-day.shtml

2.3.12 Social research gives insight into Rena volunteer experience (Joint release with BOPP/BOPRC) http://www.waikato.ac.nz/news-events/media/2012/03research-gives-insight-into-rena-volunteer-experience.shtml

12.3.12 Inquire, Inspire conference discusses research in the Bay http://www.waikato.ac.nz/news-events/media/2012/03inquire-inspire-conference-discusses-research-in-the-bay.shtml

26.3.12 The good oil on the Rena volunteer experience http://www.waikato.ac.nz/news-events/media/2012/03the-good-oil-on-the-rena-volunteer-experience.shtml

24.5.12 Rena discussed at Kīngitanga Day (released to University of Waikato website only) http://www.waikato.ac.nz/news-events/media/2012/05rena-discussed-at-kingitanga-day.shtml

1.6.12 University leads million dollar Rena research http://www.waikato.ac.nz/news-events/media/2012/06university-leads-million-dollar-rena-research.shtml

23.7.12 Tertiary partners take part in Future Focus showcase http://www.waikato.ac.nz/news-events/media/2012/07tertiary-partners-take-part-in-future-focus-showcase.shtml

26.7.12 Waikato University hosts annual stakeholder breakfast in Tauranga (mentions Te Mauri Moana) http://www.waikato.ac.nz/news-events/media/2012/07waikato-university-hosts-annual-stakeholder-breakfast-in-tauranga.shtml

Oct 2012 University's Coastal Marine Field Station becomes regional research hub (article for BOP Times Business Showcase Publication)

12.10.12 More than 30,000 samples used to assess the effect of Rena (released by Rena Recovery team) http://www.waikato.ac.nz/news-events/media/2012/10more-than-30,000-samples-used-to-assess-the-effect-of-rena.shtml

31.10.12 Coastal Marine Field Station expands Sulphur Point premises http://www.waikato.ac.nz/news-events/media/2012/11coastal-marine-field-station-expands.shtml

Nov 2012 Rena grounding boosts demand for coastal research expertise (article for "Off Campus")

9.11.12 Are we prepared for another Rena http://www.waikato.ac.nz/news-events/media/2012/11are-we-prepared-for-another-rena.shtml

10.12.12 Experts to speak at second science symposium in Tauranga (mentions scholarship students) http://www.waikato.ac.nz/news-events/media/2012/12experts-to-speak-at-science-symposium.shtml

7.2.13 Research students recognised at Tauranga’s Coastal Economic Symposium http://www.waikato.ac.nz/news-events/media/2013/02research-students-recognised-at-tauranga's-coastal-economic-symposium.shtml

19.2.13 INTERCOAST PhD research to continue in the Bay (acknowledges Bremen assistance with Rena) http://www.waikato.ac.nz/news-events/media/2013/02intercoast-phd-research-to-continue-in-the-bay.shtml

18.3.13 Cycling lecture and open day draws crowds during Seaweek (mentions Rena/Te Mauri Moana) http://www.waikato.ac.nz/news-events/media/2013/03cycling-lecture-and-open-day-draws-crowds-during-seaweek.shtml

19.3.13 Coastal marine research ramps up in Bay of Plenty http://www.waikato.ac.nz/news-events/media/2013/03coastal-marine-research-ramps-up-in-bay-of-plenty.shtml

Apr 2013 Scientists Analyse Findings from Rena Environmental Monitoring (article for “Re:Think”, University of Waikato)

Glossary

µg :	Microgram. Weight measurement. One millionth of a gram.
Biogenic :	Produced or brought about by living organisms, a biological assemblage.
BOPRC :	Bay of Plenty Regional Council.
CIA :	Cultural Impact Assessments.
Corexit :	Product line of oil dispersants used to dissipate oil spills.
CV :	Container vessel.
Dalton :	Standard unit for the measure of molecular mass.
Ecohydrology :	Interdisciplinary field studying the interactions between water movement and ecosystems.
Ecotoxicology :	The study of the effects of toxic chemicals on biological organisms especially at the population, community and ecosystem level.
EPA:	Environmental Protection Agency (USA).
Epimerized :	In an optically active compound that contains two or more asymmetric centers, a process in which only one of these centers is altered by some reaction to form an epimer.
Fibrosis :	Formation of excess fibrous connective tissue in an organ or tissue in a reparative or reactive process.
Goblet cell :	Simple glandular column-like epithelial cells whose function is to secrete mucin, which dissolves in water to form mucus.
Haematological :	Of the haematological system consisting of the blood and bone marrow.
Haemocyte :	A cell that plays a role in the immune system of invertebrates.
Hapū :	Sub-tribe(s) that share a common ancestor.
Heterogeneity :	Consisting of dissimilar elements or parts; not Uniform.Well mixed.
HFO :	Heavy fuel oil.
Hopanoids :	A collective group of natural pentacyclic compounds (containing five rings) based around a Hopane skeleton. Commonly found in select groups of aerobic bacteria and one of the most abundant natural products on earth.
Ignimbrite :	Rock formed from the deposit of a pyroclastic density current, or flow. poorly sorted mixture of volcanic ash, pumice, lithic fragments, glass shards and crystal fragments.
Interstitial :	Within spaces.
Iwi :	Tribal kin group; nation.
Kai moana :	Food of the sea.
Mataitai :	Fish or other foodstuff obtained from the sea or lakes.
Mātauranga :	Knowledge, tradition, epistemology.
Mātauranga Māori :	Māori knowledge.
Mauri :	Life essence, life force, energy, life principle.
Moana a Toi :	The regional boundaries of Te Moana ā Toi are from Athenree in the north, to Lottin Point in the south-East.
MSDS :	Material safety data sheets.
Necrosis :	Cell injury that results in the premature death of cells in living tissue.
NIST :	National Institute of Standards and Technology. A standard reference database.
NOAA :	National Oceanic and Atmospheric Administration (USA).

Otaiti :	Local Māori name for Astrolabe Reef. Alt- Otaîti or Otaiiti.
PAH :	Polycyclic aromatic hydrocarbons.
Pataka kai :	Food store.
PSP :	Paralytic shellfish poisoning.
Rāhui :	A restriction that sets aside an area and bans the harvesting of resources.
Rhyolite :	Silica rich igneous volcanic rock.
RLTERP :	Rena Long-Term Environmental Recovery Plan.
Rohe :	Area, region; boundary.
SCAT :	Shoreline Cleanup Assessement Techniques.
SIM GC-MS :	Selected ion monitoring. Gas chromatography–mass spectrometry. An analytical method that combines the features of gas-liquid chromatography and mass spectrometry to identify different substances within a test sample.
Tangata whenua :	Indigenous people of the land, first people of the land.
TBT :	Tributyltin chloride. Ship antifouling agent. No longer used.
TCP isomers :	Tricresylphosphate isomers. Found in lubricating/hydraulic oils.
Te Pae Tawhiti :	Māori economic development.
TIC profiles :	Total ion chromatogram profiles.
Tuangi :	Cockle. Intertidal estuarine clam.
Wai moana :	Sea, ocean.
Whakamutunga :	Conclusion.
Whakapapa :	Māori genealogy, ancestry, familial relationships; unlike the Western concept of genealogy.
WRO :	Weathered Rena oil.
WSF :	Water soluble fraction.

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