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Analysis of the grounding of the MV Rena in New Zealand, 5 October, 2011.

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ABSTRACT

The grounding of the general cargo vessel MV Rena near Tauranga Harbor in October 2011 was New Zealand's worst environmental disaster. The ship hit an offshore reef, creating hazardous salvage conditions, and the consequent spill of 350 tonnes of fuel oil affected 50 km of coastline and many islands. Many containers fell overboard, creating hazards for other shipping, requiring additional salvage resources, and introducing toxins to the marine environment that are still washing up six years later. The community responded to the disaster by flocking to the beaches and cleaning up the oil by hand, giving well over 20,000 hours of volunteer time. Short- and long-term environmental consequences for wildlife and the inshore marine environment are reviewed, along with the effects on the local economy, the political context and the management response. There were significant economic effects during the summer immediately following the event, but the clean-up appears to have been remarkably successful. While the above-water superstructure of the ship was removed, much of the (broken-up) hull remains on or close to the reef today. The final (legal) decision on the removal of the wreck has enabled abandonment of the wreck. There appear to be few, if any, long-term wider environmental effects although elevated levels of some contaminants are still measurable close to the wreck in 2017.

Keywords: MV Rena, oil spill, environmental effects, community response, political context, New Zealand

INTRODUCTION

At 02:14 hours on 5 October 2011, the Liberian-flagged 37,209 tonne container marine vessel, Rena, grounded on Otaiiti (Astrolabe) Reef on the eastern coast of North Island, New Zealand, as the ship approached the port of Tauranga. Tauranga is the commercial center for the Bay of Plenty region, is New Zealand's fourth largest city (population 130,000), is one of New Zealand's busiest ports, and services industries dominated by horticulture, forestry, agriculture and manufacturing (Statistics New Zealand, n.d.). A time line giving much of the detail behind this summary of the Rena grounding is at (Bay of Plenty Regional Council, n.d.a). Most statements and comments in this case study are supported by reference to web sites, media sources, unpublished reports and personal experiences, although the scientific literature is used wherever possible. I attended almost all public meetings, daily meetings and media updates during the weeks immediately following the event, and many public meetings, workshops, hearings and seminars held over the six years since the grounding. A key point of difference between this environmental disaster and many others is that a scientific research program was initiated by local marine scientists within hours of the grounding, and some days before the oil came ashore. Presentations, summaries and published reports from that research are summarized here.

The ship was travelling from the south at cruising speed (17 knots) and was reported to have changed course in order to approach the harbor more directly before its pilotage window closed at 0300 hrs (Webby, 2014). The reef is well-marked on charts, but sits below sea level at high tide and is not physically marked. Breaking waves are typical along this exposed coastline and the reef can often be seen, even at night. But the sea was calm, and the reef would not have been apparent to an alert observer if there was one on the bridge at that time. Images of the Rena on the reef can be seen at (Images of the Rena, n.d.).

The reef lies about 12 nautical miles offshore, and about 5 nautical miles from an island (Mōtītī) that is settled by an indigenous (Māori) community. Those 15 families obtain a significant portion of their food by foraging at sea and along the coastline. Coastal fishing and foraging are also a common recreational activity for residents of the region, and there is a small commercial fishery. There are many other, smaller islands and rocky atolls in the vicinity, some of which are wildlife reserves.

The grounding of the ship resulted in New Zealand's most significant maritime environmental disaster, with a recovery cost estimated at $NZ700 million (Ministry for Culture and Heritage, n.d.). Salvage removed much of the bridgework and any superstructure to 1 m below sea level, after which salvage was discontinued, although recovery of debris from the sea bottom and remnant pockets of oil within the wreck continued for some time. The stern of the wreck now rests on the sea floor, 40-50 m below the surface. The

bow section remains stuck fast on the reef with its superstructure removed. Regular storms and wave action, including a cyclone in early 2015, have moved the stern section into deeper water and continue to move remaining debris from the bow along and around the reef.

In early 2016, an independent legal process granted permission for the remains of the wreck to be abandoned on the reef (Smallman, 2016). That decision was appealed through the Environment Court in early 2017, and was upheld (Environment Court, 2017). The original applicants (defendants in the appeal) argued that further salvage would be more environmentally disturbing than abandoning the wreck, and would also be extremely dangerous for the personnel involved. Local Māori groups with a direct interest have come down on both sides of the argument, agreeing that recovery of the mauri (spiritual health) of the reef should take priority, but disagreeing on the best way to achieve that outcome. The reef was re-opened for fishing and diving after being closed for 4.5 years, but there is local pressure to support continuing ecological recovery by turning it into a permanent marine reserve. In August 2017, there is no indication of reserve status being granted, or that there will be any further salvage operations. Material from the Rena, particularly plastic beads, continues to wash up on the beach after storms, but most toxic materials have long-since dispersed.

Disaster management was the responsibility of a government department, Maritime New Zealand (MNZ), who arrived in Tauranga on 5 October 2011 and initiated the response. MNZ is a small agency whose primary responsibility is reducing risk through regulatory mechanisms (Maritime New Zealand, 2015). MNZ subsequently became the focus of a great deal of critical comment and analysis, but the reality is that it was not resourced for disaster response and did not have the planning, experience, or equipment to deal with an event of this scale. More detail on its actions is given below. A detailed and independent analysis of its response, including lessons learned, was provided by Murdoch (2013), but that report has been removed from all web sites and appears to be no longer available. In terms of the outcome, one comment in that report sums it up: “it could have been a lot worse” (p. 4 of the original report). A more recent independent summary of lessons learned is in Battershill et al. (2016).

Despite difficult and dangerous conditions for salvage, much of the debris field has been cleaned up, and the forward part of the ship has been removed to one meter below sea level. There were no serious personnel accidents, which is an impressive record given the working conditions, and indicates the extraordinary professionalism of the international specialists recruited for the job. Today, any residual salvage is being handled by local companies. Most realistic assessments accept that full removal is

essentially impossible, a view that is consistent with the decision of the Environment Court. Estimates of the cost of full removal have been wide ranging, with some exceeding NZ$1billion (SunLive, 2014).

In 2017, the Rena has receded into distant memory and it is rarely commented on through the media. However, the local community, including local members of parliament, continued to comment on the status of the wreck for some years. While there were widespread demands for full wreck removal for several years, that position was eventually tempered by time and the emerging view that the removal process is likely to be more damaging to the reef than leaving the wreck in place.

Due to their treaty status, local indigenous people (Māori) were involved in direct consultation with the ship's owners and government agencies from the outset of the incident. In addition to the direct effects of the wreck (such as toxins in sea food and physical damage to the reef), Māori are deeply concerned about effects on spiritual values, termed mauri, or life-essence (Bennett, 2015; Battershill et al., 2016). Mauri is a specifically Māori principle and concept, but there is no question that the wider community responded similarly to the Rena event as a deeply personal invasion of their spiritual connection with the environment. Today, even some Māori have accepted that the wreck is unlikely to be fully removed, and that the best option is to let the mauri of the reef recover naturally as the wreck breaks up or becomes integrated with the reef (SunLive, 2015). As the mauri of the reef was already compromised due to long-term effects of multiple human activities in the region (Bennett, 2015), that recovery will be a long process requiring careful nurturing.

THE EVENT

The ship carried general purpose cargo, and had 1368 containers on board (Webby, 2014). Also on the ship were 1733 tonnes of fuel oil (a heavy bunker oil, HFO380), and smaller amounts of other fuels and oils. Some of the containers carried toxic materials, and many more contained plastics and other materials that are potentially hazardous to marine wildlife (Battershill et al., 2016). For example, there were many containers with plastic beads used in plastics manufacturing. These beads can be ingested by fish, seabirds, and larger filter feeders (such as some whales). Huge quantities of beads were removed from beaches, and beads still wash up in 2017. A total of 32 containers held listed dangerous goods. Many more contained personal effects that could have included toxins such as paints or solvents, and there were some vehicles that would have contained oils and fuel. A significant challenge for the recovery process was that a full ship’s manifest was not made immediately available to MNZ. Even when the manifest was provided, some

items were mislabeled or poorly described, so were not immediately identified as potentially toxic or environmentally dangerous (Schiel et al., 2016).

The weather remained calm for five days following the grounding, allowing an emergency response operation to begin. The safest access was at the stern of the vessel, and initial recovery attempts focused on pumping oil from the forward to the aft tanks while it was still warm (fuel oil must be heated for pumping). Apart from access issues, the aft tanks were better protected, were less likely to rupture in a breakup, and there was the possibility that the weight adjustment would help with removing the ship from the reef.

Small oil leaks were noted on the sea surface within 24 hours, but were more likely to be volatile hydraulic oils than the heavier fuel oil. About 3 m^3 of the oil dispersant Corexit (mostly Corexit 9500, with small amounts of Corexit 9527) was used to disperse these early leaks (Webby, 2014), but use of chemical dispersants was controversial and was discontinued after a few days (Bay of Plenty Regional Council, n.d.c).

On the fifth day, the emergency response team began pumping oil off the ship to a barge. But the weather deteriorated, the ship began moving on the reef, and the pumping was abandoned. Some rupturing of fuel tanks occurred during that bad weather, and the first oil came ashore on 10 October on Mount Maunganui beach, possibly the most iconic beach in New Zealand (Figure 1). This beach at the entrance to Tauranga Harbour is a popular domestic holiday destination and site of some of the most expensive real estate in the country. Locals immediately headed to the beach with spades and wheelbarrows, and began bagging up the oil for removal (Figure 2).

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Figure 1. Mt Maunganui beach, 17 October 2011, with messaging from an unknown local (after most oil had been removed). Maunganui translates as “large mountain”, and the beach is named for the volcanic cone in the picture that anchors the sandspit and guards the entrance to the harbor. Photo by author.

Figure 2. Mt Maunganui beach with bagged oil on 11 October, 2015, 6 days after the grounding of the Rena. The children are responding to both the situation, and the cold and misty day. Photo by author.

The bad weather continued. On 12 October, the first containers fell overboard creating a navigation hazard and demanding an expansion of response capability to off-ship salvage. Attention of the public also shifted to the question: "what is in those containers?" as rumors of hazardous substances began to flow through the community. It turned out that a number of hazardous substances were on board, and further that locating and marking those specific containers (before they fell overboard or the ship broke up) was difficult and dangerous. Certainly, some were lost without being identified. The response managers, who had access to the ship's manifest, were less than transparent about the number of containers and types of hazardous substances despite direct questions about those substances at public meetings. The community was angry in principle, but was reasonably accepting of the difficulties being faced by officials in relation to the oil-spill threat. However, the lack of clarity in relation to hazardous substances contributed to an initial climate of suspicion and distrust that took some time to overcome. Indeed, the response managers arguably never entirely (re)gained the trust of the public on this issue.

On 12 October, significant oil sheens were seen on the surface from spotter planes and it was apparent that an environmental disaster was unfolding. On 13 October about 350 tonnes of oil washed ashore on Papamoa beach, which fronts a significant and relatively new coastal community about 12 km east of Mt. Maunganui beach. The oiling of this beach served to focus community action and effort, with many people responding to it as a deeply personal invasion. Oil also washed ashore in significant quantities on all of the local islands, along the coastline for about 25 km in both directions, and inside the harbor. Relatively little oil was cast further afield.

Within another 24 hours, containers and their contents began washing up on beaches to the north and south of Tauranga. Oil, containers and their contents began to move further afield, and some material even came ashore on the eastern side of East Cape, a travel distance of several hundred kilometers. The legal status of the cargo resulted in further public confusion and distrust when people were notified that they might be committing an illegal act if they retrieved any of it. Local people who were simply cleaning it up were not easily distinguishable from people collecting it to take home ("stealing"). Some of it was hazardous to wildlife (e.g. plastic beads), some was very unpleasant (e.g. thawed meat products or milk powder), and some was genuinely useful (e.g. dressed wood products).

On a global scale, the Rena oil spill was minor. However, the Rena event was one of just 6 spills of >7 tonnes of oil in 2011, with most of those being smaller than the Rena spill (ITOPFL, 2015). The industry believes (using data in the ITOPFL report) that serious spill events are decreasing in frequency, and note the 600,000 tonnes of oil that leak into the marine environment from natural sources every year (Culliford and Fairweather, 2013). However, on a local scale even relatively small spills can be devastating for marine invertebrates, wildlife, and ecosystems in an otherwise pristine environment, and oil seriously affects local amenity. It is noteworthy that a larger scale disaster from the Rena was averted, and over 1300 tonnes of fuel oil were eventually pumped off the ship and taken ashore.

ISSUES ARISING

Toxins

MNZ insisted that it was always open about the possibility of toxins being released into the marine environment. Corexit (an oil dispersant) is a recognized toxin, and its use on the first oil spills was widely criticized. Whether or not it was effective, its use was a public relations disaster. MNZ has stated that Corexit was ineffective in the rough offshore conditions (probably true, Bay of Plenty Regional Council, n.d.c), but it seems likely that the public outcry was just as important in the decision to stop using it. Corexit was found to have sublethal biotoxic effects in some local fish and crayfish (Webby and Ling, 2016).

Information about actual toxins in containers on the Rena dribbled out, alongside misinformation and rumor. Ultimately, it appears that there were no acute toxins on the Rena that represented a significant environmental threat after dilution in or reaction with salt water. However, it was initially announced that there were 23,240 kg of alkylsulphonic acid and four containers of hydrogen peroxide (Daly 2011), along with heavy fuel oil and numerous lighter oils and fuels.

On Friday 25 November (the day before a national election), MNZ announced that a further 21 toxin-containing containers had been identified (490 tonnes in total, World Maritime News, 2011). Aluminum trisodium hexafluoride, also known as cryolite, has a variety of uses (Minerals Zone, 2015), and was likely being carried as a waste product of aluminum smelting (Webby and Ling, 2016). It was listed on the ship's manifest as "cover bath material", which obscured its true status as a toxin that probably should have been declared under the international maritime dangerous goods code. Its toxicity is relatively low and it is only slightly water-soluble, but one of the uses of cryolite is as an insecticide and it is dangerous if breathed in as a powder. MNZ stated that it was not advised by the ship's insurers that cryolite was onboard (Daly,

2011b), which is why it had not been listed as such during earlier public statements about toxins. It is unlikely that the timing of this release one day before an election was coincidental, and the "discovery" was almost entirely ignored by the media. Photographs taken in 2013 show a litter of cryolite ingots on the ocean floor close to the reef (Dempsey, 2015a).

An analysis of other potential long-term toxins, including anti-fouling chemicals and metals such as copper, tin and zinc, is in Ross et al., (2016). The study indicates elevated levels of these contaminants in both organisms and the environment on the reef, and did not detect any progressive trends in concentrations over three years.

The entire reef was declared off-limits to boating, with access not reinstated until 5 April, 2016 (Newshub, 2016). Fishing pressure on the reef prior to the Rena event was not extreme as it is essentially an off-shore destination. However, its 4.5 year status as a default protected area may have resulted in ecological benefits to the wider area. The debate about whether its protected status should be made permanent (as a marine reserve) is ongoing among local interest groups, but has mostly been ignored by government despite recognition of the principle of mauri (see above). The possibility is not raised in the Rena Recovery Plan (Ministry for the Environment, 2013).

Wildlife Response

Massey University, about 300 km south of Tauranga, maintains a disaster response capability for wildlife, and that team (the National Oiled Wildlife Response Team, NOWRT) began setting up in Tauranga within 24 hours of the grounding. A wildlife rescue center was established, and teams were sent out to patrol beaches and search islands to recover oiled wildlife (Figure 3). The behavior of several of the most threatened species required that some of this searching be done at night (e.g. penguins come ashore in the evening), and these recovery surveys were difficult and at times dangerous.

Dead oiled wildlife were first seen at sea on 6 October, and the first birds were admitted to the treatment facility on 7 October (Rena Recovery, 2017). By 25 October, there were 379 birds in care, of which 211 had been cleaned and were being held for recovery, and 108 were still oiled (Bay of Plenty Regional Council, n.d.b). The majority (319) were little blue penguins *Eudyptula minor*, and there was also 1 shearwater, 1 white-fronted tern *Sterna striata*, 3 pied shags (or cormorants) *Phalacrocorax varius*, and the 60 dotterels described below. A total of 1,370 dead birds had been collected. While it appears that penguins were in the majority, the reality is that this species is much more easily captured than any of the

others because penguins come ashore in the evening and do not fly. However, some penguins were oiled as they came ashore from oil on the beaches or rocks, which is less likely for flying birds. Flying species that are oiled at sea, such as shearwaters or cormorants, rarely make it to shore and tend to drown at sea.

Figure 3. An oiled little blue penguin in the NOWRT treatment facility. Photo by author.

By 17 November there were 407 birds in care. The first treated penguins were released back into the wild on 22 November. Many local people ("hundreds") worked as volunteers alongside the vets, scientists and students from the NOWRT, who worked essentially continuously from 5 October until 23 December, when the center was demobilized. At its peak, the oiled wildlife response operation involved 250 people daily, and the number of person-hours involved is almost incalculable. The last major release of birds back into the wild occurred on 17 February, 2012. Images of the treatment facility can be seen at Bay of Plenty Polytechnic Science (2011a).

The treatment center cared for or checked up to about 2,000 birds during its operational period, which is estimated to be about 10% of the total number of birds that were oiled during the Rena event (J. Dowding, personal communication). Impacts on cetacean and fish populations are unknown. Seals are uncommon along this coastline, and the center cared for just a few seals.

The New Zealand dotterel *Charadrius obscurus* is an endangered endemic shorebird that nests along the northern coastline of New Zealand, with an important concentration of breeding birds close to Tauranga

(Dowding, 2015; Dept of Conservation, n.d.). The breeding season of these birds was just beginning in early October, and a pre-emptive (and controversial) decision was made to capture adult birds and transfer them to the treatment facility to be held until the habitat was cleared of oil. The first birds were caught on 12 October, the day that the majority of the oil spill came ashore. By 25 October, a total of 60 birds had been caught (about half the number breeding in the region), and were held for up to several months (Massey University, 2013). Direct population consequences included six dying in captivity from a respiratory disease, a few dying after being released back into the wild, disruption of long-term pair bonds, and no breeding for an entire season. However, most were released successfully back at the site of original capture and it is believed that the mortality was much lower than if the birds had been left to forage on beaches contaminated with oil (Massey University, 2013). Images of the birds and capture process can be seen at Bay of Plenty Polytechnic Science (2011b).

Captured birds did not breed in the 2011/12 summer. However, two years later, numbers of breeding pairs were similar to pre-Rena-event counts in most of the areas in which they had been captured Massey University (2013). The dotterels may even have benefitted from the Rena event, in that the publicity generated by their management has resulted in increased public awareness of their status and increased funding support for management and monitoring programs, mostly as control of introduced mammalian predators. As with most shore-breeding bird species in New Zealand, predation and disturbance by the public are the greatest threats to dotterel breeding success (Department of Conservation, n.d.).

Marine invertebrates, fish and substrates

It was widely anticipated that there would be long-term effects on marine invertebrates, with accumulation of toxins, especially oil, in the tissues, and some catastrophic mortality. It was additionally expected that there would be some accumulation of toxins in substrates around the reef, and possibly further afield (Battershill et al. 2016). Surprisingly little long-term damage has been detected (Battershill et al., 2016, Schiel et al., 2016)

During the five days of calm weather before the first major oil leak, a large team led by Professor Chris Battershill of the University of Waikato and Professor Dave Schiel of the University of Canterbury undertook extensive survey and sampling of marine invertebrates along the coast and around Otaiiti Reef and adjacent islands. These samples served as a baseline for future analyses of population demography and

toxin accumulation from the grounding and oil spill, and allowed for extensive analyses of ecological and physiological effects of an event of this type.

Detailed reports from multiple environmental studies are available at Te Mauri Moana (2013). Final reports from some of those projects are in theses (Webby, 2014; McSweeney, 2015; Dempsey, 2015b) and in a special edition of the New Zealand Journal of Marine and Freshwater Research, published in 2016 (volume 50(1)). Only the main outcomes are summarized here.

The team surveyed and sampled all habitats in the region, including rocky reefs, open beaches, offshore islands and estuaries. They examined and tested fish, invertebrates (including key seafood species), micro-organisms and substrates, testing for traces of heavy metals and hydrocarbons. The baseline for much of this work was obtained during just four days of sampling, and the researchers qualify all reports with comments about limited sample sizes, natural variation swamping oil-spill effects, unmeasured sub-lethal effects, missing data, and the need for more intensive research.

Their overall conclusion is that there were few long-lasting effects on Bay of Plenty maritime habitats.

Clear contamination has been found for both reef sediments and fauna on Otaiiti Reef (i.e. close to the grounded Rena). Both PAHs (Polycyclic Aromatic Hydrocarbons) and heavy metals were found. Contamination measures were lower at the nearby Mōtītī Island, which was extensively oiled, than at the reef itself, indicating dilution effects (Ross and Battershill, 2013).

There were measurable changes found in invertebrate communities, but the observed effects were generally swamped by extreme weather and related environmental effects (such as wave action).

For example, there was a reduction in cover (= number of individuals) of the small black mussel *Limnoperna pulex* and its associated taxa as an immediate response to oil fouling, but the measureable effects had already disappeared after one month (Schiel et al., 2013). Subsequent storm events in 2012 affected mussel cover on rocks, and associated communities, more strongly than did the oil. Tuatua *Paphies subtriangulata* is a common bivalve on exposed (oceanside) sandy coastlines, and is an important food species for humans and some fish and invertebrates. Populations showed variation in abundance, with declines from winter to summer, and smaller average sizes at heavily impacted sites (Culliford and Fairweather, 2013). The decline in population numbers may be due to natural variation and cannot be unequivocally attributed to the Rena. The possibility of differential mortality of larger individuals due to oiling needs further study. Human collection of tuatua for consumption along this coastline was mostly prohibited for five years, 2012-2016, due to biotoxin warnings (from algal blooms unlikely to be linked to

the Rena event). Populations in 2017 far exceeded densities present before the Rena event (personal observations, based on qualitative observations), indicating that predation by humans is likely to be more important than the Rena as a long-term controlling influence on tutatua densities.

In August 2012 (ten months after the Rena event), PAH residues were tested in two bivalve species *Paphies australis*, *Austrovenus stuchburyi* (both eaten regularly by humans), and a whelk *Cominella glandiformis*, sampled from 16 inner harbour locations (Taiapa and Hale, 2013). The whelk forages on bivalves and is not eaten by humans.

PAH levels were up to five times higher at contaminated sites relative to measurements of PAH residues in tissues of the same species at uncontaminated sites (Taiapa and Hale, 2013). The highest levels of tissue contamination were at sites facing the harbour entrance, where oil contamination was heaviest.

Significant variation in population densities were also found, but it was not possible to separate out natural population variation from effects of oil contamination. There was no significant variation in population parameters of bivalves (such as a catastrophic population collapse) at the most contaminated site over a two-year period. The most contaminated sites are also close to the port and a boat ramp for recreational fishers, and have therefore been subject to ongoing anthropogenic disturbance (likely including some oil contamination) for many years.

None of the tissue contamination found was at a concentration considered dangerous to human health. The possibility of odour or taste effects for human consumption was not tested.

Weathering of oil on rocks was monitored, and it was found that 90% of the oil had disappeared within 5 months (Schiel et al., 2013), presumably due to wave action.

Effects on fish and crayfish species of PAHs and cryolite (see toxins below) were studied in the laboratory under controlled conditions of exposure regarded as reasonably representative. Juvenile fish species are particularly susceptible due to their high surface area, thin membranes or integuments, and planktonic lifestyle (references in Muncaster, 2013). Short-term (48 hrs) effects, including organ and structural damage, were found for planktonic stages of the kingfish *Seriola lalandi* (Muncaster, 2013). Sensitivity was to both hydrocarbons and the dispersant Corexit. Sublethal effects involving erythrocyte swelling and haemoconcentration were found in short-term exposure of subadult individuals of other fish species studied, and differential haemocyte counts were found in rock lobsters *Jason edwardsii* (Ling, 2013). Effects of PAHs on growth of algae were similarly studied in the laboratory. Algal cells subject to contamination had higher growth rates and higher mortality than uncontaminated cells (Reihana, 2013).

Effects on microbial communities indicate that communities subject to contamination were more similar (i.e. less diverse) than communities from uncontaminated sites (Carey, 2013). The causes are likely to be either addition of the oil as a resource for certain microbial species, or differential survival of certain species in the presence of the contaminant.

Salvage boats were sourced urgently from overseas, and were put to work immediately on arrival. Two vessels, a cargo barge and a tug were eventually discovered to have extensive biofouling assemblages that included new species for New Zealand, and potential pest species (Smith et al., 2016). The vessels were cleaned after six weeks, but additional effort was required searching around the area in which they worked for possible occurrence of these imported species (none were found). The authors note that biosecurity issues should be included in any response planning designed to respond to future events of this type.

Community response

The response of the local community to the oil spill was possibly unique. Local residents demonstrated their willingness to help by flocking to the beach and cleaning up the oil. They were initially discouraged by MNZ and local authorities from doing so, due to the negative experiences with volunteer labour that other authorities had encountered in similar situations (Sargisson et al., 2012a). However, residents were determined (Lockwood et al., 2016) and in response to that persistence, systems were set up to register, train, and manage a volunteer workforce of up to 10,000 people (Figure 4). In total, 19,725 hours of beach clean-up activities were logged by volunteers after that organisation was put in place (Sargisson et al., 2012b). Some thousands of hours would also have been given by volunteers before any recording began, and many additional volunteers worked in more remote areas where there was little or no structure to support them, and no recording of their activities. While much of the time given was by local people, volunteers also came from much further afield, particularly Auckland (200 km) and Hamilton (100 km), but also from all over the country.

For example, local indigenous people organized a clean-up at Maketū (about 20 km east of Papamoa), where more than 450 volunteers spent a total of 3356 hours cleaning the beach and rocky foreshore (Smith et al., 2015). The total population of Maketū is 1047 people (including children), thus almost half of the entire population supported the clean-up.

Not only did the use of volunteers provide a fast and effective way of removing oil from beaches, but this approach was beneficial for the volunteers themselves who reported that they enjoyed the

experience, found it personally therapeutic (Hamerton et al., 2015), and stated that it improved their connection with community (Sargisson et al., 2012a).

Figure 4. Volunteer crews sifting sand on Papamoa Beach. The tractors hauled people and bagged sand/oil, and worked below the tide line as much as possible in order to minimize compression effects on the sand. Hundreds of people were working on the day this photo was taken covering perhaps 10 km of beach. Photo by author.

Incorporating indigenous knowledge and social networks contributed to the efficacy of the response by the strongly indigenous group in Maketū, and participation in the restoration of their environment enhanced well-being of the community as a whole (Smith et al., 2015). As noted by one participant "it is all about the hearts and minds, which is much less tangible than monitoring results".

Many people in New Zealand feel connected to their environment (Sargisson and McLean, 2015), and also believe that the relationship between people and the environment needs repair as a result of human resource use and impact. That relationship is captured by the principle of environmental restoration, which combined with a strong sense of urgency was clearly a fundamental driving force behind the enormous volunteer turnout during the Rena event. However, the need to restore mauri was equally fundamental, if

more difficult to understand and not so clearly defined. Mauri represents the spiritual wellbeing of the environment (in this case, the reef, and the oiled coastline), and exists independently of people (Bennett, 2015). It overlaps with the notion of Gaia, the principle that the planet is a self-regulating living system (Ogle, 2004). An environment with a healthy and intact mauri is more likely to function as a self-regulating ecosystem, and as a consequence will likely benefit people in many ways.

Economic consequences

On 24 January 2012, the steel-hulled Rebecca May, an 18 m commercial deep-water fishing boat, hit an underwater object near Whitianga (about 100 km to the north) and sank in 15 minutes (Waikato Times, 2012). Although the cause of this accident has never been explained, it is likely that the boat hit a lost container or other debris from the Rena. Fortunately, the crew escaped unharmed, but incidents such as this are examples of the many unpredictable consequences for local businesses and communities.

Tauranga supports numerous marine-focused small businesses, such as wildlife tour operators (whale/dolphin watch), fishing charters, diving charters, boat-based tours, boat maintenance workshops, and so on. Mount Maunganui is a boutique domestic tourist destination, with numerous accommodation providers, cafes, restaurants and specialist shops in the village. It also hosts many cruise ships through the summer, some of which bypassed Tauranga in the post-Rena summer of 2011/12. Private, boat-based recreation is a major focus of holiday activities in the region.

The consequences of the Rena event for private boat-owners included the direct threat of sinking, restrictions on movement, the possibility of catching contaminated fish, the possibility of oil in engine intakes, and the insurance implications of hitting a container or other debris on the water (insurance was voided). As a result, boating and fishing activities through the summer of 2011/12 were much-reduced and some people presumably went elsewhere for their vacations.

The effects on local businesses depended strongly on their business focus. Some land-based accommodation and food providers benefitted from the arrival of contracted specialists who worked on the Rena. They also likely lost some business due to people going elsewhere for the summer holidays.
Specialist marine-based tour operators reported losing most of their business overnight, with some describing a catastrophic rate of cancellations. Several specialist fishing shops either closed or restructured their business activities. During subsequent compensation hearings, a local campground described its losses as being in the hundreds of thousands of dollars. Several businesses indicated that several years passed

before they returned to pre-Rena turnover levels. Some businesses closed down. During compensation claims, many business people pointed to the stress and trauma of a failing business as just as significant a consequence as the direct economic losses (Bay of Plenty Times, 2014).

A few local boat, plane and helicopter charter operators gained business from Rena-based activities. However, the highly specialized nature of the salvage requirements meant that most people and much of the equipment that was used came from elsewhere (usually overseas), under contract or charter. Thus, much of the insurance money that might have compensated for lost local business revenue did not remain in the local economy. We have heard international contractors state that they used locally-based businesses and labor whenever they could, and we have no reason to doubt that claim. But the specialist skills and equipment required were of a standard not usually found in small local marine-based operations, and had to be sourced from the international market. Also, the sudden increase in demand for specific marine equipment and skills likely overwhelmed the local supply, even if it was available.

There was also considerable dissension created in the local business community when some local operators obtained Rena-based contracts, whereas others did not. As those who did not had usually lost business anyway, there was significant potential for the development of a sense of righteous indignation, charges of bias and corruption (whether substantiated or not), and simmering resentment. The long-term effects of those essentially psychological effects can only be guessed at, but there is no doubt that some friendships were destroyed, some informal business partnerships collapsed, and at least some of the cooperation that usually characterizes a network of small local business disintegrated.

Little, if anything, was done in the short-term to support small marine-based businesses that were under immediate economic threat, despite regular comments by them through public meetings and the media. They eventually received some support and compensation, but it was highly regulated and was not granted in the time frame needed to allow businesses to remain viable during the summer immediately following the event. The New Zealand government has legislation in place enabling a rapid response when a state of emergency (such as drought or flooding) is declared, but this catastrophe appeared to be outside the normal legislative frameworks and economic support for local businesses was slow to arrive.

The political and regulatory context

The navy was brought in to provide general support, including the specialist role of checking and clearing sea lanes in and out of the harbour. They continued in a variety of roles for some months. A positive outcome

of this support was no significant disruption to shipping from the port despite the frequent presence of containers floating near the surface. The proportion of operational costs shared between the insurers/owners of the Rena, and the taxpayer as ultimate funder of the navy, is not known to us.

The Rena grounded just 6 weeks before a national election, and served to distract much of the country from the electoral issues of the time. The initial government response involved an attempt to contain and minimize the scale of the disaster, with MNZ insisting that the situation was under control and that they had the appropriate response skills and capacity. Neither was true (Murdoch, 2013), and MNZ's attempts to take control were ignored by the public who continued to flock to the beaches to clean up the debris and oil. Most of these people were voting age, and they were angry. The local MPs, all of whom were in the ruling government coalition (locally, they were in either the dominant National Party, or the minority Māori Party), were very concerned about the Rena turning the public against the government during the election campaign. There was also the possibility that other election candidates would use the Rena to turn the public against sitting MPs.

The sitting local National Party MPs chaired many public meetings, whereas electoral candidates from other parties were given no opportunity to either sit on the stage or speak, apart from as a member of the public from the floor. Rena consultation meetings became default election meetings, and were used to raise the profile of the local MPs under the guise of "supporting the Rena response". Some scheduled election meetings were cancelled due to the focus on Rena activities, and local National Party MPs attended none of the public election meetings that were eventually held. Realistically, the sitting MPs gained far more media and public attention through being seen to be involved in the Rena response than they could achieve by attending election meetings.

It rapidly became apparent that the public would not be contained or stopped from cleaning beaches, and further, that they were being exposed to toxic fumes and chemicals. Thus, the MNZ response strategy shifted to a more inclusive approach, with daily news briefings and regular public meetings, and involvement of local government. A coordination center was established (which employed up to 200 people at its peak), a coordinator of volunteers was appointed, a registration and team structure was initiated, and protective equipment was sourced and provided for free. In total, close to 10,000 people registered to work on volunteer clean-up crews, and many of these worked multiple four hour shifts on the beaches sifting through sand in order to recover and bag patches of oil (Figure 4) and other items. A total of 950 tonnes of waste oil, contaminated sand and debris was removed from the beaches (Ministry for Culture and Heritage, n.d.).

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It is possible that the local politicians (including sitting MPs) did not immediately grasp the gravity of the situation or the significance of the potential consequences. Local government politicians initially deferred to MNZ, and were reluctant to either engage with the issue or comment publically. After a few days, it became clear that: 1) members of the public were going to clean the beaches whether or not they were invited, 2) a catastrophe of unprecedented proportions was unfolding, 3) MNZ was unable to deal with the situation on its own, and 4) the Rena event provided an opportunity for political exposure and grandstanding by both sitting MPs and other election candidates. After five days of little comment, the public was suddenly inundated with an over-supply of information through public meetings, marae-based meetings (specific to Māori), daily media updates, TV news reports and more. Almost every political leader showed up for a photo opportunity holding a spade on the beach. There were numerous (essentially misinformed and unverifiable) promises that "the Rena will be removed".

A shift in response strategy was initiated and the public outpouring of action and support became better organized and coordinated. The public became an essential tool for cleaning oil off the beaches, with more specialized crews working the rocky shores. The public were also much better informed and were given regular opportunities to vent their anger at public meetings, although with little real ability to influence events.

Response of the ship owners

We have not attempted to tease out the complex relationships and responsibilities amongst the ship owners, charterers, insurers and crew. Nor is it appropriate to name them here. However, there was frequent comment in public statements by officials and the media about the ownership of responsibility demonstrated by the ship's owners. They visited regularly, and devoted considerable time and effort to ensuring that all local environmental laws and regulations were adhered to, that those who suffered genuine costs were compensated, that wildlife recovery and monitoring programs were funded, and that concerns specific to local communities and indigenous peoples were addressed. Several senior crew of the Rena eventually received jail terms, and after release were supported by the owners to return to their home countries. The owners appear to have accepted responsibility and responded appropriately.

Conclusions

If small, locally-owned business with a common interest (in this case the sea) were networked through a common organisation (such as the local Chamber of Commerce), their ability to negotiate support in an emergency situation could have been enhanced.

The timing of the Rena event just before a national election was unfortunate, as local MPs were distracted from what should have been key roles of supporting local businesses and showing leadership on environmental issues. Some of the fall-out effects on small businesses might have been reduced if local MPs had focussed on a liaison and support role, as they likely would have done at another time. For example, their involvement could have resulted in more effective negotiations with the owners and insurers of the Rena, perhaps resulting in greater employment of local expertise and equipment. They might have negotiated short-term subsidies or interest-free loans for local business owners in order to allow them to remain viable as the event and its consequences unfolded. Loans could have been repaid when compensation claims were eventually processed, a process that took several years.

The initial paternalistic and obstructive nature of the government agency in charge of the Rena response (Maritime New Zealand) led to serious distrust by the community, exacerbated as it emerged that the agency was not resourced to deal with a disaster of this magnitude. A more open and inclusive approach from the beginning would likely have resulted in much better local relationships, a more immediate focus of emotional energy on action rather than anger, and a more supportive community overall. However, it is accepted that MNZ had no previous experience of an event of this magnitude, was responding appropriately within its operational mandate, and was flexible enough to change its response behaviour in the face of events that it could not control or manage.

During oil spills on sandy shores elsewhere, the public have been excluded from the clean-up and government agencies have brought in heavy equipment to remove oil off the beaches. It is impossible to use such equipment without driving over oil, and the compression effects of wave action and vehicles has forced oil deep into the sandy substrate, making it almost impossible to remove and creating a heritage problem with emerging oil (Battershill et al., 2016). In the case of the Rena, most oil was removed by large numbers of people using spades and sifting the sand by hand, resulting in almost no compression of oil into the sand. As a result, most of the oil was gathered up very quickly and there has been very little long-term residue continuing to emerge on the beaches.

Subsequent to the Rena event, there were numerous calls for more and better regulation of coastal shipping (Radio New Zealand, 2012; Maritime Union of New Zealand, 2012), but that discussion has now faded away. To date, there has been little attempt to reform shipping regulations, and review of the MNZ

statement of intent strategic document for 2015-2021 (Maritime New Zealand, 2015) suggests that much of it was written before 2011 (e.g. it contains no reference to the Rena). The Maritime Union was still commenting in its blogs on the need for better regulation in 2014 (Maritime Union of New Zealand, 2014). The reasons for resistance by MNZ to firming up the coastal shipping regulations are not stated. Rather, there is a clear statement of preference for a minimum of regulation.

The outpouring of anger and action that emerged as a grass-roots community response had enormous environmental, social and psychological benefits, the value of which can only be guessed at. However, the redirection of community anger into effective low-impact beach-cleaning action was an extremely positive and unexpected outcome of the Rena event.

It appears that there has been remarkably little long-term ecological or environmental damage from the Rena event. At least some of that outcome can be attributed to the community response on the beaches, along with the work of professional teams who cleaned rocky outcrops and headlands by hand. The contribution of the professional salvage teams that worked on the wreck itself and the supportive response of the owners and insurers certainly reduced the immediate threat and beach-side clean-up requirements. Presumably, environmental resilience also contributed, although the extent of that contribution remains for a future analysis.

A final decision on the Rena has now been made, with the Environment Court decision to support leaving the remainder of the wreck on the reef. Remnant materials of relatively low toxicity are still scattered around the reef, and the question of whether to convert the reef into a marine reserve is now rarely commented on. The wreck attracts divers, but exposure of the reef, depth of the stern portion, and distance offshore all limit its potential as a safe diving destination. Fishers reported some good catches when they first returned to the reef, but fish numbers apparently returned to pre-Rena densities relatively quickly. The beaches are just as clean and well-used as they were pre-Rena, and any potential issues with human consumption of oil-contaminated shellfish were averted by the 5-year biotoxin prohibition. The Rena event flagged the relatively lax coastal shipping regulations operating in New Zealand, but there has been little tightening of those rules. Since the event, the Port of Tauranga has increased both capacity and channel depth, enabling access for larger ships. There has also been a dramatic increase in the number of cruise liners using the port. The emphasis is on business-as-usual, with the massive community concern for environmental issues evident during the event fading along with the memory of those traumatic days.

COMPETING INTERESTS

There are no competing interests in relation to this article.

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