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South Atlantic Natural Capital Assessment: Waste management report for Tristan da Cunha.

ENVIRONMENTAL RESEARCH INSTITUTE SOUTH ATLANTIC

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Review table

Name	Reviewed by	Date
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1. Introduction

This study contributes evidence to a programme of natural capital assessments (NCA) being implemented by the UK Joint Nature Conservation Committee and conducted by the South Atlantic Environmental Research Institute (SAERI) in the UK South Atlantic Overseas Territories. Funded by the Foreign and Commonwealth Office managed Conflict, Stability and Security Fund (CSSF), the work sits under its Environmental Resilience programme which includes objectives to integrate natural capital considerations into economic and social development planning.

The SAERI NCA Project Manager visited Tristan da Cunha in November-December 2018 and discussed a range of potential natural capital assessments with the Administrator and Tristan da Cunha Government heads of department. Waste management was raised as an important issue on the Island and this document sets out the ***potential*** risks that Tristan da Cunha Government may be exposed to if the current waste management regime is maintained, and offers some solutions from other small islands.

2. Background

The Tristan da Cunha archipelago, consisting of the 'northern' cluster of Tristan, Nightingale and Inaccessible, and Gough Island 410 km to the southeast of Tristan, are some of the most remote in the world, being separated from the nearest mainland by nearly 2,800 km of open ocean (Figure 1). The archipelago's EEZ covers 754,720 km^2, whilst the total land mass covers just 178.3 km^2. Gough and Inaccessible Islands are designated a UNESCO World Heritage site for their near-pristine environments and vast populations of breeding seabirds and pinnipeds.[1]

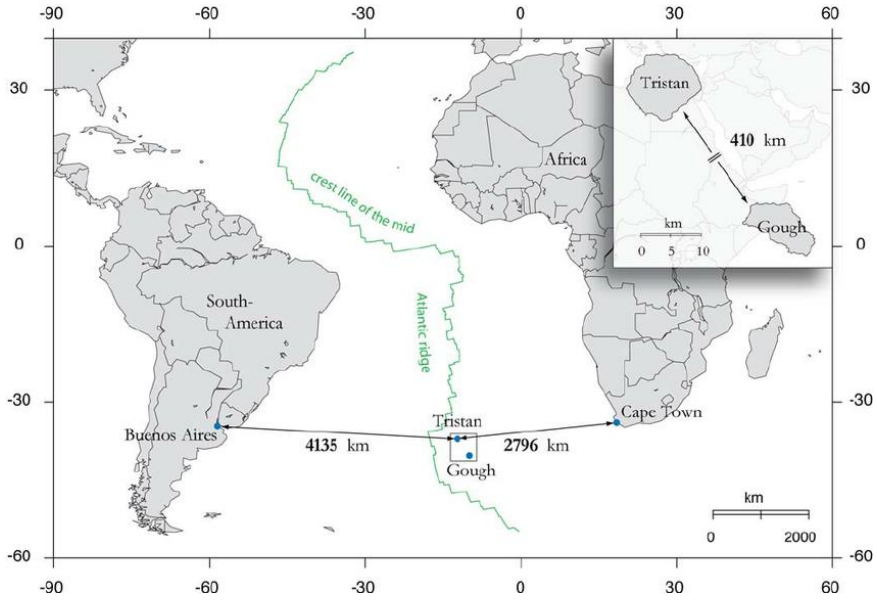

Figure 1: Location of Tristan da Cunha archipelago[2]

[1] UNESCO World Heritage Site listing. https://whc.unesco.org/en/list/740

[2] Source: Groenenberg, Dick & J Beintema, Albert & Dekker, R & Gittenberger, Edmund. (2008). Ancient DNA Elucidates the Controversy about the Flightless Island Hens (Gallinula sp.) of Tristan da Cunha. PloS one. 3. e1835. 10.1371/journal.pone.0001835.

The northern group of Islands have a mild-temperate, oceanic climate and sit near the belt of the 'roaring forties' - strong westerly winds found between 40-50°S which causes the weather to be highly changeable. Most of the 40 km of Tristan's coastline is very steep, with cliffs rising to 600m in places, and the only habitable part of the Island is the settlement plain, located to the north west of the Island (Figure 2). The Island is still volcanically active, and an eruption in 1961 led to a full evacuation of the population for two years.

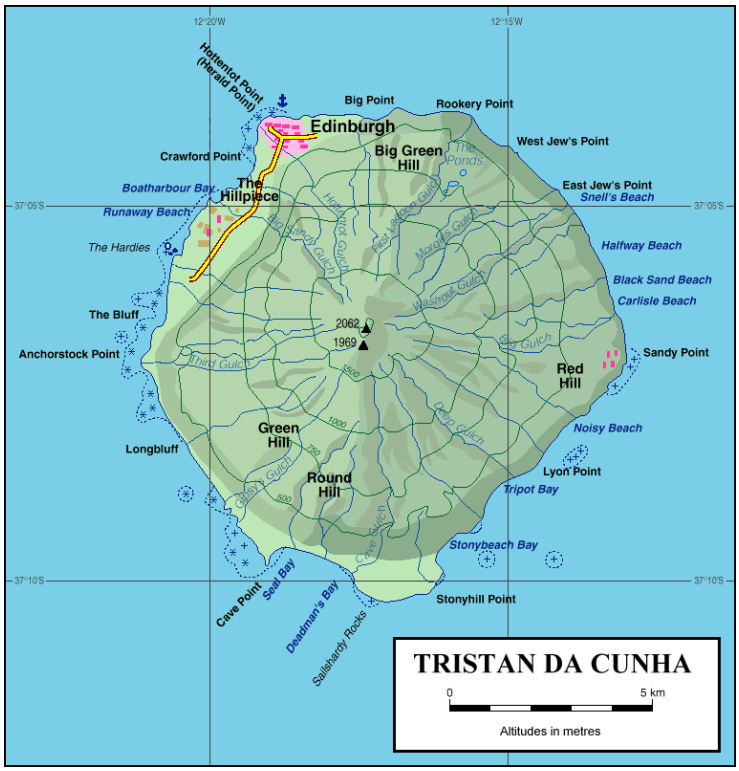

Figure 2: Map of Tristan Island showing settlement plain to the north west[3]

Tristan is the only inhabited island – with the exception of 6-8 expedition members manning the South African weather station on Gough. The current population consists of 230 Islanders, and 10 expatriate workers and their families and visitors, all living in Edinburgh of the Seven Seas – generally just referred to as the 'village', or 'Settlement'. A further 26 resident Islanders are currently overseas[4]. There are approximately 120 private homes on the Island. The Island has an ageing population and low birth rate, whilst immigration is presently restricted to those that marry a resident Islander.

Tristan da Cunha's economy was based on traditional subsistence agriculture and fishing, which generated food for the consumption of the local population and it only started to move from a barter economy to a cash economy in 1942, when the Naval Station, located there during WWII, paid wages in cash. The commercial fishery for Tristan lobster began in 1949 which brought a significant change to the Island's economy. Today Islanders still grow their

[3] Map sourced from http://mcee.ou.edu/bweaver/Ascension/tdc-topo.htm
[4] As of 07/05/19 - https://www.tristandc.com/population.php

own crops – especially potatoes – rear cows for beef and milk, sheep for wool and mutton, as well as hens and ducks for eggs. There is also a Supermarket which imports groceries from the UK and, principally, South Africa. Products include flour, sugar, frozen bread, canned goods, and sodas in both cans and plastic bottles (Figure 3). This has inevitably led to an increase in household waste, but quantities and type of waste are not recorded.

Figure 3: Tristan's supermarket, otherwise known as the 'Canteen'.

3. Waste management on Tristan

Waste water is managed through a gravity-fed system to two septic tanks which were installed in 2015. All food waste such as peelings, leftovers etc., are fed to the Island's 700[5] chickens and ducks, so the bulk of household waste consists of packaging from imported food goods and broken hardware and electrical goods. Household waste is collected by a team of up to seven people, using a tractor and trailer, once a week and then taken to the Island 'landfill' dump which sits on the 1961 lava flow 985m to the east of the Settlement (Figures 4a and 5), where it is burned in the open. Hazardous and non-hazardous waste is not separated, and some hazardous waste does end up being burned. There also appears to be casual fly-tipping along the tracks and pathways threading through the lava flow and, in addition, there are areas where large industrial machinery have been dumped throughout the lava flow (Figures 4b and 5) over several decades.

[5] As of April 2019.

Figure 4: Google Earth image of Edinburgh of the Seven Seas (The Settlement) clearly showing a) the 'landfill' dump and b) discarded machinery lying within the 1961 lava flow.

Figure 5: Photographs of the landfill dump, top left, and surrounding area. Bottom photo corresponds to Figure 4b.

4. Potential risks of the current waste management system

Waste management is a global issue and is particularly challenging on small Islands with limited resources. Industrial recycling is not economically viable on Tristan due to the relatively small quantities of waste produced and cost of shipping to a suitable recycling facility. There are, however, simple measures which could be taken to improve the current waste management system on Tristan, which are set out in section 5. With the current waste management system on Tristan there are ***potential,*** interconnected, risks including health, environmental, reputational and economic. Important considerations associated with the confidence we can attach to these potential risks actually occurring on Tristan are discussed.

4.1 Human health risks

Open burning of waste, the method used on Tristan, is a fast, effective and inexpensive way to reduce waste which typically involves burning at low temperatures. It is common throughout small Islands and low income countries. Worldwide scientific research, however, has demonstrated that burning of waste at dumpsites produces air toxins[6], released at ground level, and can also lead to soil and water pollution and even food contamination.

Items from modern household waste contain various combinations of tens of thousands of man-made chemical compounds, and burning this waste in the open releases them. Significant amounts of greenhouse gases are released into the atmosphere, including carbon dioxide, methane and particulate matter. Exposure to these emissions can lead to cases of respiratory disease[7]. Another pollutant particularly associated with open burning, is the emission of persistent organic pollutants including polycyclic aromatic hydrocarbons, dioxins and furans, all of which are carcinogenic and have been linked to a variety of other diseases. It has also been shown that single exposure to pollutants released by the burning of plastic bags can worsen diseases such as asthma and chronic obstructive pulmonary diseases[8]. They are also known to cause developmental damage to unborn foetuses and young children[9], although scale needs to be taken into consideration as these studies were on much bigger populations producing large quantities of waste.

Ash also builds up at open burning sites. Bottom ash, accumulating from leftover solid material can distribute toxins through the soil. Fly ash accumulates from exhaust gases rising up during the burning process and contains a high content of a variety of toxic pollutants. It is carried by the wind for long distances and once it falls to surface level it can be inhaled by humans, enters food chains when animals ingest it, or enters and pollutes water sources[10].

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[6] International Solid Waste Association. Wasted health - the tragic case of dumpsites, 2015.

[7] Rinku Verma, K.S. Vinoda, M. Papireddy, A.N.S. Gowda, Toxic Pollutants from Plastic Waste- A Review, Procedia Environmental Sciences, Volume 35, 2016, Pages 701-708,ISSN 1878-0296.

[8] Rinku Verma, K.S. Vinoda, M. Papireddy, A.N.S. Gowda, Toxic Pollutants from Plastic Waste- A Review, Procedia Environmental Sciences, Volume 35, 2016, Pages 701-708,ISSN 1878-0296.

[9] Velis, C., & Mavropoulos, A. (2016). Unsound waste management and public health: The neglected link? Waste Management & Research, 34(4), 277–279. https://doi.org/10.1177/0734242X16638632

[10] Anju Elizbath Peter, S.M. Shiva Nagendra, Indumathi M. Nambi. Comprehensive analysis of inhalable toxic particulate emissions from an old municipal solid waste dumpsite and neighborhood health risks. Atmospheric Pollution Research, Volume 9, Issue 6, 2018, Pages 1021-1031. ISSN 1309-1042,

Leachate (the liquid which runs from the bottom of a dumpsite as waste breaks down) is also know to contain multiple toxic chemicals which can be absorbed into soils and waterways[11].

Whilst it is challenging to establish links between the burning of solid waste and public health, there are some robust case studies. A study in Campania, Italy, revealed that there were an estimated 848 cases of premature mortality and 403 cases of fatal cancer per year considered to be a consequence of exposure to dumpsites with hazardous waste[12]. Epidemiological studies have found that two main health outcomes – cancer and congenital malformations – are statistically associated with waste exposure in dumpsites[5]. The health of children is particularly affected by environmental conditions; for example half the children and adolescents living near a Kenyan dumpsite had respiratory ailments and blood lead levels exceeding the international threshold.[13]

Waste in open sites can also become a breeding ground for vermin, flies, and other potential carriers of communicable diseases.

Important considerations

It is important to note that health risks of exposure to open burning of waste depend on the practices followed, on the type of the waste disposed of in each dumpsite, as well as on the environmental and social conditions of an area. Factors which affect the level of exposure include:

- Location
- Geological / hydrogeological conditions
- Local climate
- Local flora and fauna
- Solid waste streams, composition and quantity
- Area covered by waste

The waste management team on Tristan know the best times to set fire to waste to avoid it blowing over the Settlement, and the prevailing westerly winds disperse gas and particulate matter, which most likely prevents any great build. An analysis of wind data from 2016 (Figures 6, 7 & 8), however, shows that the wind was in an easterly direction 15% of the year and there is therefore still potential for pollutants to reach the Settlement, which is only 985m from the landfill dump. Fly ash could also be settling over pasture land and the Patches. **To better understand any potential health impacts of the current open burning of waste on Tristan, on-site sampling, monitoring and a more detailed analysis of wind patterns would be required. Further study would also be required to understand if leachate is able to penetrate the lava, although studies suggest this may be possible[14].**

[11] International Solid Waste Association. Wasted health - the tragic case of dumpsites, 2015.

[12] Carla Guerriero, John Cairns, The potential monetary benefits of reclaiming hazardous waste sites in the Campania region: an economic evaluation, Environmental Health 2009, 8:28 doi:10.1186/1476-069X-8-28

[13] Global Waste Management Outlook. United Nations Environmental Programme and International Solid Waste Association. 2015. ISBN: 978-92-807-3479-9.

[14] Sanjay S. Kale, Ajay K, Kadam , Suyash Kumar , N. J. Pawar (2010). Evaluating pollution potential of leachate from landfill site, from the Pune metropolitan city and its impact on shallow basaltic aquifers. Environ Monit Assess (2010) 162:327–346. DOI 10.1007/s10661-009-0799-7

Figure 6: Average wind direction for Tristan Island for 2016, overlaid on the Settlement a) and the location of the landfill dump (b).

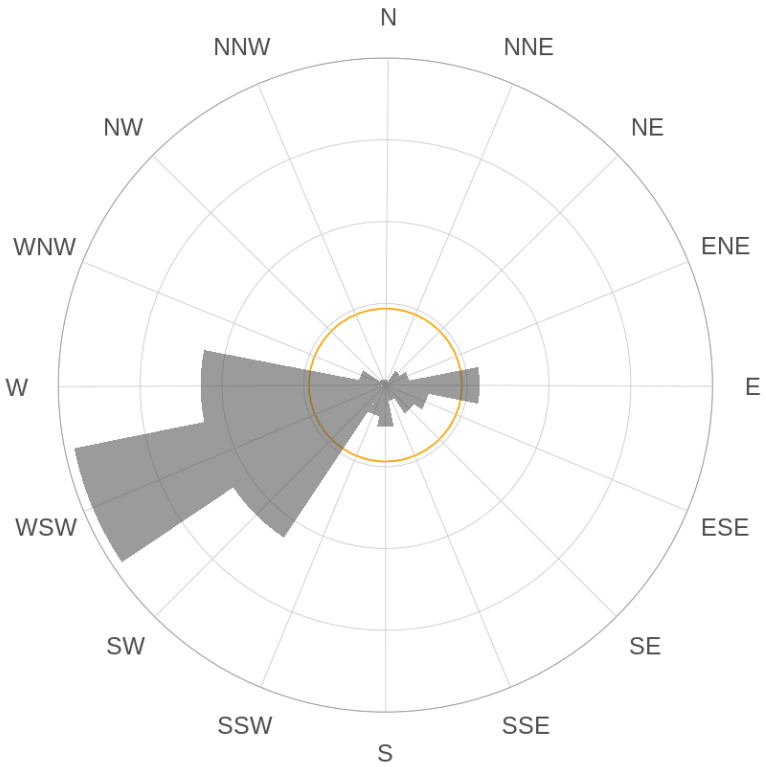

Figure 7: Average wind direction for Tristan Island in 2016. Orange circle represents 'no data'.

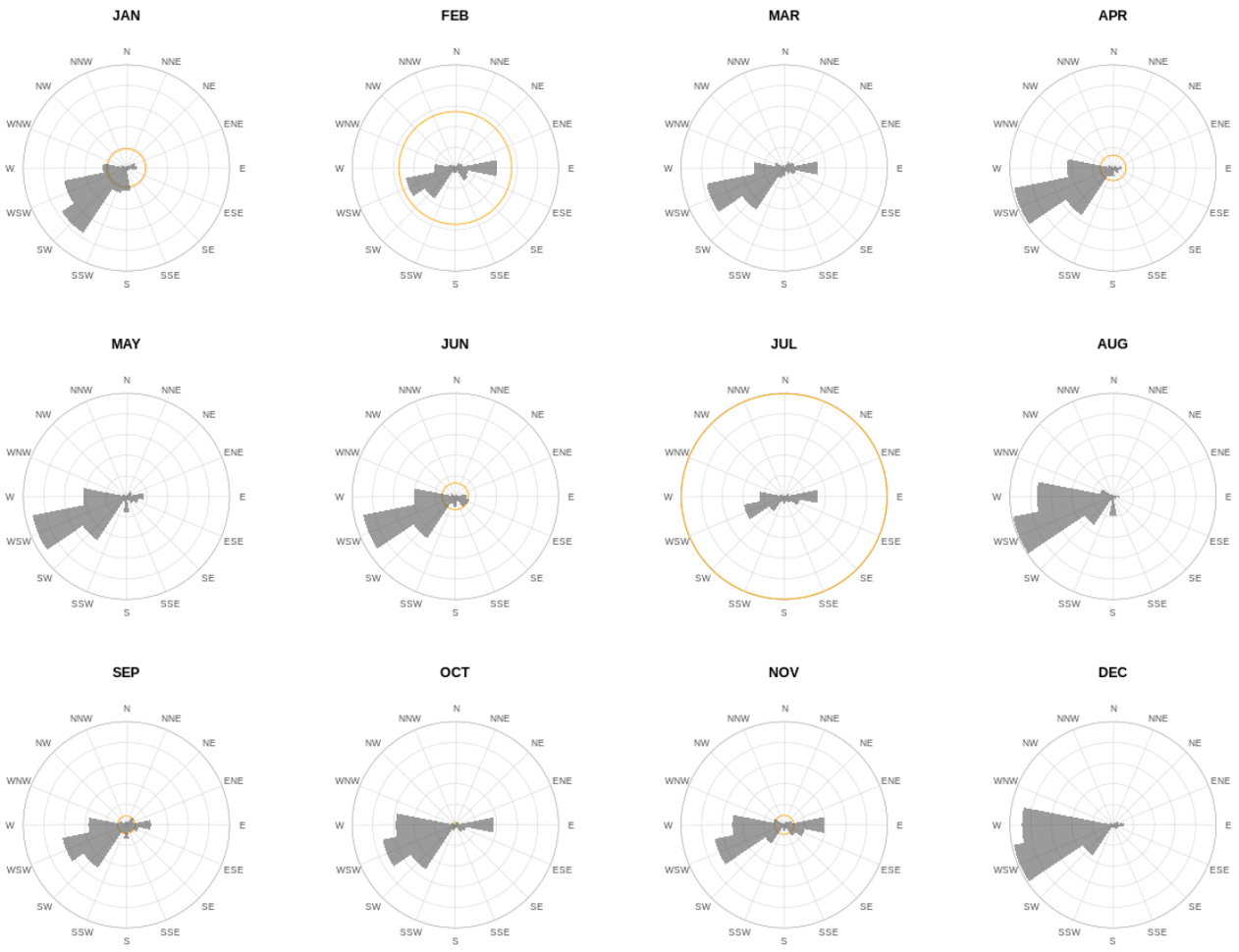

Figure 8: Monthly wind direction for Tristan Island in 2016. Note the seasonal and monthly variation.

4.2 Environmental risks

As well as the potential health risks of burning open waste, metals such as cadmium, copper, lead and zinc released during open burning can have a harmful effect on soils and ultimately plants and the animals that feed on them. Depending on the nature of the metals, they can end up either in water held in the soil, or leached into aquifers. Plants can also absorb chemicals through their leaf surfaces as a result of fly ash falling. This can alter soil chemistry which affects organisms in the soil and plants which grow there[5,15] and there is evidence that this can ultimately affect plant life cycles[16]. Animals and fish can also ingest the pollutants and accumulate them in their tissues, affecting breeding, growth and health. When these plants

[15] D. Voutsa, A. Grimanis, C. Samara, Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter, Environ. Pollut., 94 (1996), pp. 325–335

[16] Syeda Maria Ali et al, Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city, Journal of King Saud University - Science Volume 26, Issue 1, January 2014, Pages 59–65

and animals are eaten, pollutants are passed on to humans[17] with the associated health problems discussed in section 4.1.

As open burning of waste typically happens at low temperatures, the waste tends to smoulder over long periods of time and this can result in materials not being fully burned. These materials are then picked up and blown around by the wind, particularly lighter plastics, or left to further degrade into microplastics. Plastics can also be blown around as waste is tipped at the dumpsite[5]. Given that the Tristan landfill dump site is only 160m from the sea, and the constant winds on the Island, it is almost inevitable that plastics and microplastics are entering the inshore marine environment.

A recent paper by Barnes et al[18] showed that marine debris on beaches in the South Atlantic Overseas Territories, including Tristan, had increased by more than tenfold in the past decade. Sea surface plastics had also increased, even hundreds of meters down on seamounts (Figure 9). Plastic fragments < 5 mm (microplastics) were most abundant, comprising 35% of items, followed by plastic bottles, fishing-related items and films. They also showed that of 2,243 animals (comprising 26 species), plastics had been ingested by primary consumers (zooplankton) to top predators (seabirds) at high rates.

Public awareness of the impacts that plastics have on the environment has risen dramatically in recent years, and the implications of this are discussed in section 4.3. The impacts of microplastics within the marine environment are less in the public domain but have major implications for the health of marine species – we focus here on lobster because of its importance to the Tristan economy - and humans that rely on them. Many commercially important marine species have been shown to ingest microplastic particles, and laboratory experiments confirm that this can result in harm to these species.

One paper which examined the ingestion of microplastics in 15 different marine zooplankton species showed that 13 (87%) of them, including lobster larvae, had ingested microplastics which impacted on their health[19]. As these form the basis of most marine food chains, microplastics are passed up the food chain to other species. Adult lobsters are one such species and, because they are omnivorous, consume many other animals – such as crustaceans, polychaete worms and bivalves – which are known to ingest microplastics. One study has shown that as many as 83% of lobsters (*Nephrops norvegicus*) in Clyde Bay, Scotland, contained microplastics and it is believed that these remain long-term, if not permanently, in the animals[20]. These plastics can lead to blocked digestive tracts and the

[17] Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Open burning of waste, including burning of landfill sites. Published by the Secretariat of the Stockholm Convention on Persistent Organic Pollutants in October 2008.

[18] D.K.A. Barnes, S.A. Morley, J. Bell, P. Brewin, K. Brigden, M. Collins, T. Glass, W.P. Goodall-Copestake, L. Henry, V. Laptikhovsky, N. Piechaud, A. Richardson, P. Rose, C.J. Sands, A. Schofield, R. Shreeve, A. Small (2018). Marine plastics threaten giant Atlantic Marine Protected Areas. Volume 28, ISSUE 19, PR1137-R1138, October 08, 2018. https://doi.org/10.1016/j.cub.2018.08.064

[19] Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J. & Galloway, T. S. Microplastic ingestion by zooplankton. Environ. Sci. Technol. 47, 6646–55 (2013).

[20] Murray, F. & Cowie, P. R. Plastic contamination in the decapod crustacean *Nephrops norvegicus* (Linnaeus, 1758). Mar. Pollut. Bull. 62, 1207–1217 (2011).

build-up of toxins within the animal[21], the latter is believed to be a factor in deaths of lobster from 'Shell Disease' over the last decade in Long Island Sound, USA[22].

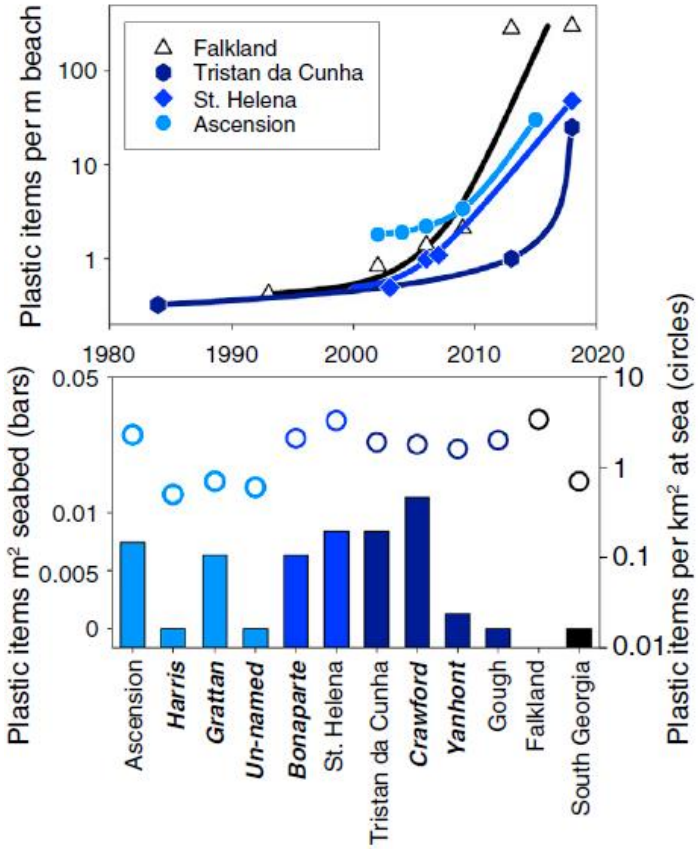

Figure 9: (Top) Increase in shore-stranding plastic with time and (bottom) plastic density levels found on seabed (bars) and sea surface (circles) by South Atlantic location. Source Barnes et al (2018).

Whilst the impact of larger pieces of plastic litter on seabirds has been well known for several decades, new evidence has shown that some seabirds appear to be particularly susceptible to the ingestion of microplastics, particularly those feeding on the sea surface, such as fulmars, albatross, shearwaters and petrels. This can inhibit feeding leading to starvation and also exposes seabirds to contaminants associated with plastics which may negatively impact on the birds' fitness[23].

[21] Microplastics in marine environments: Occurrence, distribution and effects Norwegian Institute for Water Research, 2014. ISBN 978-82-577-6489-0.

[22] Multiple factors in marine environments affecting lobster survival, development, and growth, with emphasis on alkylphenols: a perspective. Hans Laufer, Ming Chen, Bryan Baclaski, James M. Bobbitt, James D. Stuart, Yuegang Zuo, Molly W. Jacobs. Canadian Journal of Fisheries and Aquatic Sciences, 2013, 70:1588-1600, https://doi.org/10.1139/cjfas-2013-0148

[23] Microplastics in marine environments: Occurrence, distribution and effects Norwegian Institute for Water Research, 2014. ISBN 978-82-577-6489-0

Important considerations

The pollution risks of open waste burning come with similar caveats to the health risks outlined in section 5.1 and any study of this could inform the probability of environmental risks. The issue of plastics and microplastics reaching the shallow marine waters around Tristan are more complicated. Globally, the main sources of marine plastic are land-based, from urban and storm runoff, sewer overflows, beach visitors, inadequate waste disposal and management, industrial activities, construction and illegal dumping[24]. Ocean-based plastic originates mainly from the fishing industry, nautical activities and aquaculture. Barnes et al[25] suggest that more than 70% of plastics found in surveying the shore, sea surface, water column and seabed of South Atlantic Overseas Territories were of non-local origin. This does, however mean that there could be up to 30% of plastics entering Tristan waters from the Island itself, currently making any reputational challenges harder to defend. **To better understand any potential impacts on the lobster fishery and other marine species, a continuation of the research conducted by Barnes et al 2018 to specifically cover ingestion of microplastics by Tristan lobster, as well as bioaccumulation within the food chain, would be essential.**

4.3 Reputational risks

The Tristan da Cunha archipelago is widely acknowledged to be one of the few remaining places in the world with a near-pristine temperate marine ecosystem with high abundance of species and a well-managed rock lobster fishery[1,26]. On this reputation it attracts scientists and documentary makers from around the world. Tristan is also portrayed in the press as an idyllic paradise[27] which harks back to 'simpler' times, and it has many international followers on social media who are drawn to this – Tristan Post & Tourism Facebook page, for example has 5.8k followers and comments often refer to the beauty of the Island e.g. "*how i wish, i am there to enjoy the beautiful tristan da cunha*" and "*Such a beautiful and clean place where nature is at its best*…"

Due to its remoteness and limited sailings to the Island tourism is, and will most likely remain, only a small part of Tristan's economy but it does bring in much needed income for the Island in the form of cruise ship calls and the occasional intrepid traveller. The 2017-18 season net revenue from tourism was just over £50,000 and it has been estimated that, with the increase in demand for niche-expedition style cruises and a few adjustments to local prices, this

[24] https://www.iucn.org/resources/issues-briefs/marine-plastics

[25] D.K.A. Barnes, S.A. Morley, J. Bell, P. Brewin, K. Brigden, M. Collins, T. Glass, W.P. Goodall-Copestake, L. Henry, V. Laptikhovsky, N. Piechaud, A. Richardson, P. Rose, C.J. Sands, A. Schofield, R. Shreeve, A. Small (2018). Marine plastics threaten giant Atlantic Marine Protected Areas. Volume 28, ISSUE 19, PR1137-R1138, October 08, 2018. https://doi.org/10.1016/j.cub.2018.08.064

[26] Caselle JE, Hamilton SL, Davis K, et al. First quantification of subtidal community structure at Tristan da Cunha Islands in the remote South Atlantic: from kelp forests to the deep sea. PLoS One. 2018;13(3):e0195167. Published 2018 Mar 29. doi:10.1371/journal.pone.0195167

[27] https://www.nationalgeographic.com/travel/tristan-da-cunha/, https://www.nationalgeographic.com/people-and-culture/food/the-plate/2015/06/17/hard-core-locavore-eating-on-the-worlds-most-remote-Island/, https://www.freemansperspective.com/freedom-paradise-found/

could rise to £135,000 by 2024[28]. The UK Government Blue Belt programme is also working with Tristan da Cunha's Government to establish a marine protection strategy for its EEZ by 2020[29] and with this comes a public expectation that human impacts such as marine litter will be managed[30].

The 2017 screening of the BBC's Blue Planet II programme raised public awareness of the impact of plastics on the marine environment to unprecedented levels. Recent research shows that searches of 'plastic recycling' rose by 55% following the programme's appeal in the final episode, alongside significant growth in searches for conservation charities[31]. In the UK, 60% of people surveyed by a supermarket now use a refillable water bottle, and the same supermarket has seen an 800% increase in questions about plastics from its customers[32]. Millennial consumers in particular are demanding curbs on plastic and waste.

There are even religious calls to address the problem of marine plastics; a 2017 letter from Pope Francis to the 'Our Ocean, an Ocean for Life' conference stated "We cannot pretend to ignore the problems of ocean pollution resulting, for example, from plastic and microplastics that enter the food chain" whilst the Indonesian Government has joined forces with the country's two largest Islamic organisations to encourage consumers to reduce plastic waste[33].

This all leads to increasing international scrutiny on those areas of the world, like Tristan, which are considered to be 'sentinels of global ocean pollution', and with it an increasing exposure to reputational risk as a result.

Reputational risk is best understood in the business world, where negative publicity can lead to major financial implications. The perception that a firm is a source of plastic pollution exposes it to a reputational risk that may result in loss of value to the corporate brand and loss of interest by investors. It is argued that up to a ¾ of a company's value is tied to its reputation. Poor environmental performance can also lead to organisations being unwilling to invest in a company, an example being the billions of dollars being divested from fossil fuel companies over the last few years[26].

Whilst it is much harder to prove reputational risk from a Governmental perspective, it is evident that tourists and expatriate specialists visiting and working on Tristan have concerns. The open burning of waste and discarded objects strewn across the 1961 lava flow is unsightly, which was acknowledged in the brief for the 2016 RIBA design ideas competition[34], and comments from recent visitors[35] include:

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[28] Acorn Tourism, Dawn Repetto and Ness Smith. South Atlantic Natural Capital Assessment; Tristan da Cunha tourism assessment, 2019.

[29] https://www.tristandc.com/wildlife/bluebelt.php

[30] https://greatbritishoceans.org/, https://www.imas.utas.edu.au/news/news-items/clean-up-mission-for-remote-Island-polluted-by-38-million-bits-of-plastic,

[31] https://resource.co/article/attenborough-effect-searches-plastic-recycling-rocket-after-blue-planet-ii-12334

[32] Waitrose & Partners Food and Drink Report 2018-19

[33] Risk unwrapped: plastic pollution as a material business risk. Client Earth report, July 2018.

[34] http://www.ribacompetitions.com/tristan/brief.html#background

[35] Personal communications with author.

"*In such a remote location, I would expect a pristine and untarnished environment, and for the local people who live there to be living in harmony with their environment. Unfortunately, the waste management on the Island is unsightly and unpleasant to see. It also concerns me that the choice of how and what products to import to the Island and how the disposal of those products many be managed to reduce pollution, harm to wildlife and to allow the population to sit better alongside the natural environment does not appear to be considered at all*."

"*There are also large amounts of broken glass, sharp metal and other dangerous objects. The immediate practical requirement is, perhaps, for the Island Council to consider the present arrangements and implement a more controlled and regulated disposal procedure for domestic rubbish, and to control fly-tipping*."

"*In terms of large item disposal, it is a complete mess up there*."

"*My initial impression was 'wow, what a mess, how can they have let it get like that?!' especially the fact that the rubbish was strewn over such a large area. It was certainly impressive in scale, but it seriously detracts from Tristan's aspirations to be seen as ultra-ecologically-friendly*."

Important considerations

Reputation is defined as 'beliefs or opinions that are generally held about someone or something'. In today's social media age, reputations can be built and broken extremely quickly and it is also difficult to predict what the press might pick up on. As described in sections 4.2 and 5.2, the rapid increase in marine plastics on Tristan's beaches and within its EEZ cannot be blamed on Islanders, with over 70% assessed to be of global origin. That said, UK media and social media in particular could easily, at best, misinterpret information and, at worst, manipulate images and information to create 'fake news'[36]. **The best way to avoid reputational risk is by upgrading the current waste management system.**

4.5 Economic risks

Health, environmental and reputational risk all lead to economic risks. Section 4.1 highlighted that in Campania, Italy, there were an estimated 848 cases of premature mortality and 403 cases of fatal cancer per year considered to be a consequence of exposure to dumpsites with hazardous waste. Economic analysis revealed that if these waste-associated deaths were eliminated, the benefits to the economy would be an estimated €11.6 billion (approximately £10.1 billion) at the time of the study[9]. A report by the OECD[37] sets out per-person costs of the willingness to pay by Governments to avoid the health impacts from exposure to particulate matter as a result of open burning of waste. These are set out in table 1 below.

[36] See https://www.thatsnonsense.com/photo-claims-to-show-litter-in-hyde-park-after-environmental-protests-fact-check for a recent example.

[37] Hunt, A. (2011), "Policy Interventions to Address Health Impacts Associated with Air Pollution, Unsafe Water Supply and Sanitation, and Hazardous Chemicals", OECD Environment Working Papers, No. 35, OECD Publishing. http://dx.doi.org/10.1787/5kg9qx8dsx43-en

Table 1: Per-person costs of health impacts associated with exposure to particulate matter and ozone

Health Impact	Range of costs per incidence (USD, 2010 ppp)
Acute bronchitis	453-512
Chronic bronchitis	170 000-500 000
Respiratory hospital admissions	2 000-24 000
Cardiac hospital admissions	200-29 000
Asthma symptom day	38-54
Asthma attacks	75-280
Restricted activity day	30-150
Minor restricted activity day	38-53
Respiratory symptom day	6-50
Emergency room visit	80-670
Work loss day	80-150

Economic valuations of the environmental impacts from open burning of waste are less abundant, but there have been some studies, including one in Palau. This shows that the value of fish resources (reef fish, lobsters and crabs) lost due to land-sourced pollutants was estimated at USD $88,000 per year[38].

Reputational risk management has a major impact on tourism around the world. There are many examples which show loss of tourism income as a result of poor waste management practices – in Tangiers, this was estimated at USD $23 million per year and in Palau at USD $960,000 per year. Willingness to pay surveys in St Lucia and Trinidad and Tobago estimated that the cost of the impact on residents and tourism from the loss of aesthetic values (as a result of poor waste management) were USD $27 million and USD £3 million per year respectively[10].

5. Potential solutions

Tristan is already successfully starting to address its waste management practices. In 2011, under a grant from the UK Government, through the Department for International Development, a GP3 Glass Imploder was purchased (Figure 10). Flyers were sent out to the community to explain how and why glass would be recycled, and a dedicated shed set up for recycling[39]. This continues to be used and the crushed glass put to various uses on the Island[40]. There is an ongoing beach litter monitoring programme set up by the Conservation Department and more recently Tristan has started to conduct beach cleans and has built awareness raising of ocean plastics into the school curriculum[41]. School children are currently collecting plastic bags and putting them into plastic bottles to create 'eco-bricks'. There is, however, no mention of waste management in the strategic

[38] Hajkowicz, S., K. Tellames, J. Aitaro (2006). Economic cost scenarios for solid waste-related pollution in Palau.IWP-Pacific Technical Report.
http://pacificwater.org/userfiles/file/IWRM/Toolboxes/financing%20IWRM/Palau.pdf

[39] https://www.tristandc.com/tristangoesgreen.php

[40] Sean Burns, personal communications, April 2019.

[41] https://www.tristandc.com/news-2018-06-12-worldoceanday.php and https://www.tristandc.com/school/news-2019-01-30-Caves-clean-up.php

plan for the Island 'Tristan da Cunha's Compass to Our Future' which was reviewed in May 2018.

Figure 10: Glass crusher in action .

5.1 Island models

As discussed in section 4, waste management on small, remote Islands is a global problem and Tristan da Cunha is far from alone in the challenges it faces. Pitcairn Island, a UK Overseas Territory is located in an isolated region of the Pacific, with its administrative headquarters in Auckland New Zealand, 5310km (3300 miles) away. The population of Pitcairn Island is approximately 50 people and the land area is just 4.6 km^2. Within its strategic plan for 2014-2018, it sets out a clear objective to 'Develop a waste management centre to manage waste and recyclable materials', under which it set out to;

- Construct a building to facilitate the management of all waste and recycling.
- Address hazardous waste by finding a safe method of removal from Pitcairn.
- Raise community awareness of new waste facility and procedures.
- Develop waste regulations

An accompanying report[42] sets out a series of practical solutions to reduce and manage waste, which could easily be adapted for Tristan (Appendix I). Knowledge exchange with other small Islands and UK OTs, including St Helena which has transformed its waste management system in just a few years, would also enable Tristan to adopt and adapt existing best practice. Ascension Island is also in the process of upgrading its waste management system, including the installation of an incinerator and recycling centre[43] (Figure 11) and a recent report by Blue Marine Foundation sets out this process and provides useful links and examples from St Helena[44]. A Cost Benefit Analysis of waste

[42] Solid Waste Management Guideline for Pitcairn, June 2016.

[43] Developing a Waste Management Strategy for Ascension Island. A Waste Treatment Technology Review prepared as a first stage in the development of a Waste Management Strategy for Ascension Island. Wrap consultants, July 2017.

[44] Waste Management on Small Remote Islands: An Ascension Island Case Study. Leigh Morris, January 2019. Blue Marine Foundation.

management on St Helena has also been produced as part of the South Atlantic Natural Capital Project, which could help inform options on Tristan (Appendix II).

Figure 11: New incinerator and recycling centre on Ascension Island. Source, Blue Marine Foundation.

5.2 Reduce waste

Current waste management best practice focuses on 'zero-waste' hierarchy models (Figure 11) which prioritises the reduction of waste. This sits well with Tristan's strategic plan objectives A.3 and A.4 which set out to 'Reduce reliance on Cape Town foodstuffs by 20% within 5 years and 80% over 10 years' and [therefore] increase Government reserves due to a reduction in importation of food stuffs' and 'Ensure greater self-sustainability of livestock and other food stuffs on the Island [leading to a] reduction in the cost of living due to self-sufficiency, ensuring the long term viability of the community' respectively. Tristan Islanders also have dietary-associated health problems, so Government policies which aim to reduce the import of items such as bottled fizzy drinks and other processed foods in plastic packaging would be a sensible way to improve health as well as waste management. This may prove unpopular at first, as it did when a 'sugar-tax' was introduced on St Helena, but could provide multiple benefits.

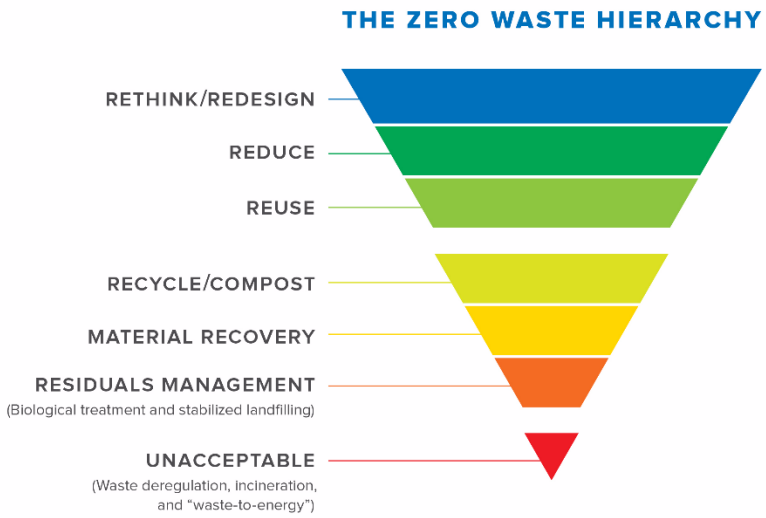

Figure 12: Zero-waste model of waste management. Source; Energy Justice Network.

To better understand what is currently being disposed of, it would be helpful to conduct a waste composition study. St Helena Government compiles an annual waste wheel (Figure 12), by analysing an average of four household waste samples, taken quarterly to account for seasonal changes (e.g. extra packaging at Christmas). This will help to inform waste and purchasing strategies on Tristan.

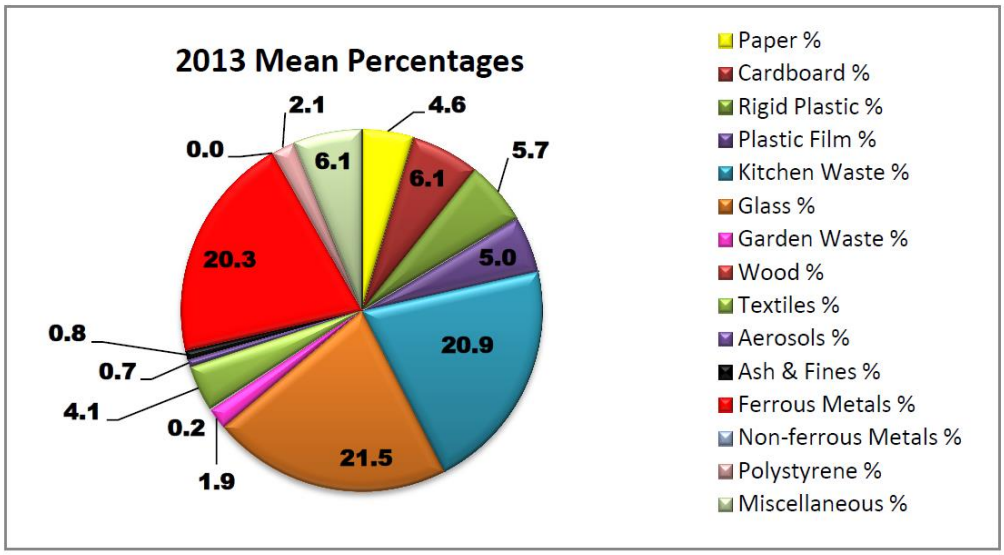

Figure 13: St Helena waste wheel for 2013.

5.3 Reuse

Due to the Island's isolation and the difficulty of importing goods, Tristan Islanders are naturally highly resourceful and items are repurposed multiple times. Most items which reach the landfill dumpsite have few remaining uses. That said, there are larger discarded items which could be used to create a more structured waste management site – examples of which are shown in Figure 14. Recycling is more challenging, but the

community has shown that it is possible with the separation of glass and use of the glass crusher. If plastic bottle imports are reduced and more aluminium cans imported in replacement, there could be the possibility to recycle these. The St Helena waste management cost benefit analysis (Appendix II) showed that the value of aluminium cans would cover the costs of recycling other less valuable and potentially hazardous items, removing them permanently from the Island. A compactor/ baler would be needed to process aluminium cans, at a cost of £8,000 - £10,000 but it was estimated that £15,000 might be generated per annum after processing and shipping costs. Whilst regular shipments of crushed aluminium cans would not be financially viable as in St Helena, an annual or bi-annual shipment could at the very least remove these items from Tristan and, at best, create income for the Island.

Figure 14: Old heavy plant tyres on St Helena (left) and oil barrels on Ascension Island (right) being used to create structured bays for management of different waste products and recycling. Source, Blue Marine Foundation.

5.4 Contained incineration

Open burning of waste is illegal in many countries due to, amongst other issues, the health risks identified in section 4.1 and, along with reducing waste in the first place, eliminating this should really be a priority for Tristan. A 2017 report on waste management for Ascension Island Government[45] identified small scale incineration as the best option, over landfill, for Ascension Island as it reduces leachate and greenhouse gas emissions (providing the ash is buried).

The report found that approximately 900kg of waste per person per year is produced on Ascension; it is likely that Tristan produces a similar amount per person, or slightly less, which would necessitate an incinerator that was capable of handling approximately 500kg of waste per day. There are many companies now specialising in small-scale incinerators, which can handle amounts as low as 50 tonnes of rubbish/day. The Ascension Island report identified that a second hand small-scale (300kg/hr) incinerator would cost £170,000 or a new one at £327,000 (both ex. shipping and taxes). Gas

[45] Developing a Waste Management Strategy for Ascension Island. A Waste Treatment Technology Review prepared as a first stage in the development of a Waste Management Strategy for Ascension Island. Wrap consultants, July 2017.

emissions would still occur, but at lower levels and dispersed higher into the air column. Additional 'scrubbers' could be fitted to further reduce emissions.

There are also small scale waste-to-energy systems available, designed particularly for remote communities[46]. These systems are so advanced that they eliminate nearly all emissions and produce heat and hot water, reducing reliance on expensive fuel imports. They are, of course, more expensive but, given the current reliance on Ovenstone for fuel and energy production, this could also be a way to decouple one of the services linked to fishing and a way of reframing Tristan's 'business' model.

Finance to procure a small scale incinerator or waste-to-energy incinerator could be sought from UK Government, which funded the Ascension Island incinerator through the FCO CSSF[47].

Alternatively, it is possible that some of the scrap metal on the Island (Figure 13) could be repurposed to build a simple incinerator that would burn waste at much higher temperatures than open burning and at least reduce leachate, airborne plastics and some greenhouse gases. An example of such an incinerator is shown in Figure 14.

Figure 15: Scrap metal on the Island which could go towards building an incinerator

[46] See https://www.cogentenergysystems.com/applications/ and https://www.inciner8.com/small-waste-to-energy-plant.php for examples.

[47] https://www.gov.uk/government/publications/conflict-stability-and-security-fund-programme-summaries-for-overseas-territories-2018-to-2019

Figure 16: Example of a low-cost 'home-made' incinerator using old shipping containers. Image source: Waste-to-Energy on a Very Small Scale: The Metlakatla Indian Community Experience/GBB Solid Waste Management Consultants.

5.5 Governance, education and behaviour change

Tristan would benefit from a waste management strategy which sets out a clear commitment and vision for improving its current system. This should include, at the very least, a code of conduct for Islanders, plus a means of monitoring the implementation of the rules that work within the cultural environment of the Island. Political and community will, and consequent behaviour changes, are also essential to ensure Tristan's waste management system is developed and thus avoid the risks set out in this document. Pitcairn received financial help for improving its waste management from the Secretariat of the Pacific Community and both Ascension Island and St Helena have been awarded Darwin Plus and other UK Government funding to help them with strategic waste planning and management, so this could be a potential funding route for Tristan to pursue.

Tristan in already moving in the right direction by celebrating World Ocean Day and incorporating beach cleans and plastic collection into the school curriculum, but an adult education 'campaign' would help to bring the community together to confront and address their current waste management system and work together to improve it. A simple name change from the 'landfill dumpsite' to something such as the 'waste management site' will help to reframe the way people think about waste, as the word 'dumpsite' provides an open invitation to do just that.

Field experiments have shown that people litter significantly more often in littered environments, compared to clean environments and, in most studies, this effect is substantial. It has also been shown that reducing the amount of litter items on the ground reduces overall littering rates in an area[48]. Given the current scattered nature of litter across the landfill dumpsite, and levels of fly-tipping, this appears to hold true on Tristan.

With a small population and full employment on the Island, any significant clean-up operation would be a major task. It has been shown that communities that work together to segregate waste and reduce littering tend to enhance community cohesion[49]. Whilst Tristan Islanders have limited time and competing demands for work, beach cleans have been successful, so perhaps similar events could be arranged to clean up the areas surrounding the landfill dumpsite over the course of a year or two. A good starting point would be to create sorting bays, as described in section 6.3, placing any smaller, easily transportable scattered waste into these to encourage people to use them.

The larger discarded items are more of a problem, but the Island does have heavy machinery which would enable scrap metal to be moved to one location, which could then, as a minimum, be contained within sorting bays. If funding could be found it might also be possible to bring a crusher to the Island – large scale industrial machines are available to rent – to compact old metal items for shipment and recycling, thus removing them from the Island for good.

6. Conclusions and recommendations

Tristan Islanders are a resilient community who understand and live within their environment. Their waste management system has, however, fallen behind current best practice and it is recommended that it should be better managed to avoid a series of ***potential***, interconnected, risks including health, environmental, reputational and economic. Further study to establish the nature and extent of these risks is required.

This document has drawn on a wide range of peer-review and grey literature to provide an overview of these potential risks but **none can be proven without further, on the ground, research.** We recommend, however that in parallel to, and/or independent of, any future research, steps are undertaken to implement a long-term strategy to improve waste management on the Island. Recommendations include:

- In the short-term, or if open burning of waste is to continue without change, ensure that waste is only burned when strong westerly winds are blowing. If not already doing so, ensure that all waste workers wear suitable protective masks to avoid close inhalation of gases.

[48] Dur, R. and Vollaard, B. (2013), "The power of a bad example: A field experiment in household garbage disposal", Environment and Behaviour, Tinbergen Institute Discussion Paper, ref. TI 2012-061/1 and Beacons of litter: A social experiment to understand how the presence of certain littered items influences rates of littering. Journal of Litter and Environmental Quality. June 2017.

[49] Global Waste Management Outlook. United Nations Environmental Programme and International Solid Waste Association. 2015. ISBN: 978-92-807-3479-9.

- Conduct on-site sampling, monitoring and a more detailed analysis of wind patterns to better understand if airborne emissions are reaching the Settlement. Further study would also be required to understand if leachate is able to penetrate the lava and enter water courses.
- Conduct a waste composition survey to better understand what waste is currently going to the landfill dumpsite and use this to develop a long-term strategic waste management plan which includes the possibility of purchasing a small scale incinerator.
- Seek outside funding and identify suitable consultants to help with the above.
- Exchange knowledge with other small islands who are facing the same challenges as Tristan; there are many innovative and realistic solutions already available which Tristan can adapt and adopt.
- Set up a series of community clean-up days to clear up litter and smaller items lying around the landfill dumpsite, and repurpose barrels to build simple sorting bays to keep waste tidy and encourage better practices.
- Reduce imports of packaged goods, particularly those contained in plastics.
- Continue to build on existing educational programmes and develop an adult education programme to ensure the community is on-board with waste management changes.
- Working with the UK Blue Belt programme, build on existing marine plastics research to determine if Tristan lobster are ingesting microplastics and, if so, to what extent.

APPENDIX I: Solid Waste Management Guideline for Pitcairn Island

Solid Waste Management Guideline for Pitcairn Islands 2016

https://integre.spc.int/images/telechargements/A_Solid_Waste_Management_Plan_for_Pitcairn_Is.pdf

APPENDIX II: St Helena Waste Management Cost Benefit Analysis report

St Helena Cost Benefit Analysis, Waste Management

https://hub.jncc.gov.uk/assets/0cf5c4ed-bdbd-44d1-8309-5c77b205ad86