Ministry of Marine Resources

Manihiki Lagoon - Strategic Environmental Assessment for Removal of Derelict Black Pearl Farming Infrastructure

May 2015

Executive summary

Pearl farming has been an important aspect of livelihood of the Manihiki community since the Early 1980's. There was significant expansion in the pearl farming industry in the 1990's. Cyclone Martin had a serious deleterious effect on the pearl farming industry on Manihiki and many people never returned to the island. Despite this, production and total sales (NZD$18M) of pearls peaked in 2000. Ever since then, the production and sales have declined through disease out breaks, lower production rates, and declining pearl quality.

MMR, in agreement with New Zealand Ministry of Foreign Affairs and Trade (MFAT), have commissioned this environmental assessment to assess the feasibility of removing of derelict pearl farming equipment within the lagoon, with the longer term view to revitalise the Manihiki Pearl industry, and create jobs and improve community wellbeing.

Objectives

The objectives of the project include:

- Assessment of the environmental impact of removing discarded farming equipment from the lagoon;
- Feasibility / cost benefit analysis of removing and disposing of the farming equipment;
- If required, identify a preferred methodology for lagoon clean up that can be implemented in a safe, fiscally viable and ecologically sensitive manner.

The overall goal of the project is to revitalise the pearl industry on Manihiki to improve the livelihood of the community.

Scope

The scope included:

- Undertaking field inspections of derelict pearl farms
- Undertaking and documenting land based activities that have the potential to impact Manihiki Lagoon
- Document and literature review
- Assessing feasibility and impacts of leaving derelict equipment in the lagoon vs removal
- Review statutory context of removal of derelict equipment
- Assess and identify appropriate clean up methodologies
- Undertake cost / benefit analysis

Primary Issues

The primary issues that contribute to abandonment of pearl farming equipment and poor lagoon health include:

- Current enforcement regime by council for non-compliant current permitted farms is ineffective, leading to increased stock densities and sub-optimal farming conditions;
- Lack of enforcement means that the abandonment of equipment may occur again in the future;
- Permits reportedly all expire in March 2015. It is likely that inactive currently permitted farms will also be abandoned.

- Departure of families from the island has contributed to the abandonment of pearl farming equipment;
- Perceived family entitlement to historically farmed areas, restricting removal of abandoned equipment and expansion of permitted farms into new areas;
- Insufficient labour force to undertake the required work, which potentially leads to further abandonment of equipment.
- Discarded live oysters beneath abandoned farm infrastructure (and also permitted farms) appear not to have been considered in lagoon carrying capacity calculations / stock census, therefore stock levels may be well under estimated.
- Discarded live oysters (beneath permitted and abandoned farms) are likely to be a significant contributor of nitrogen in the lagoon, therefore impacting water quality;
- It appears that the nutrient balance in the lagoon may be nearing the threshold for eutrophication, and further decline in water quality may have further deleterious affects on the Manihiki pearl culture / industry;
- Biofoulant on abandoned and permitted farms are likely to be contributing to nutrient loading of lagoon water;
- Floats at surface from abandoned farms pose a navigational hazard.

Clean-up Feasibility / Impact Assessment

There is a net benefit to undertaking the clean-up of abandoned pearl farms. The largest benefit will be the improvement of lagoon water quality over time. Historic anecdotal evidence suggests that better quality pearls are produced with improved water quality. The added benefit is that it will free up additional areas for pearl farm expansion – however expansion will need to be appropriately controlled to ensure long term sustainability.

Statutory Assessment

Based upon our review – legislation should not restrict the clean-up operations. Section 27 of the marine resources act Marine Resources Act 2005 requires permission from the person/entity who/that installed the equipment. MMR informed GHD that the Island Council has the authority to remove this equipment under the Manihiki Island Bylaw.

This means that any contractual arrangements for the clean-up operation will need to be considered carefully, to ensure that any contractors are acting as agents for the Island Council. We recommend legal advice be sought on contractural arrangements for removal of the derelict equipment.

Clean-up methodology

The proposed clean up methodology comprises:

- Engagement of a commercial dive team to work with local dive team for the salvage work
- Land based team from the community will be needed for sorting and processing of wastes
- Ropes are proposed to be disposed locally in a purpose excavated pit
- Floats and miscellaneous waste to be disposed at Aitutaki, subject to acceptance by the Aitutaki Island council
- Reuse of ropes is not desirable for farmers. Reuse of floats is commonly practiced, however the supply of low cost China Aid funded floats may make reuse less palatable.

- Recycling of the plastic is feasible, however likely to be cost prohibitive
- Disposal of Manihiki is considered the most pragmatic option, however will need to be carefully managed to minimise environmental effects
- Collection of discarded or dropped live oysters is critical to the success of the clean-up operations
- The shell recovered (estimated to be 88t) from the oysters have an appreciable value, and it is calculated that recovered saleable shell may have a total market value in the order of $264,000.

Rough Order Costs

The rough order costs are anticipated to be in the order of $360-460K.

Cost / Benefit Analysis

Immediate removal of derelict farming equipment from the lagoon will result in a Benefit –Cost Ratio of 9.98 and a present value of $3,849,666

Recommendations for Clean-up

- Awareness raising and meetings with the community and pearl farmers is required to get “buy in” and the need for holistic change
- Combination of commercial dive team and local dive team for salvage operations
- Local onshore team for sorting wastes
- Combination of disposal on Manihiki and disposal on Aitutaki

Recommendations for Pearl Farming Practices

- Ban discarding or “banking” surplus oysters in the lagoon
- Ban the removal of biofouling of active farm equipment within the lagoon. Biofouling should be disposed on land on the ocean side of the atoll
- Strengthen island council enforcement
- Monitor more closely the disposal of terminated oyster shells in the lagoon.
- Bond farmers to ensure removal of equipment
- Community awareness on lagoon ownership
- Setting and monitoring maximum farmed shell limits

Recommendations for land based activities

- Bund installation around generator diesel supply tanks. Secondary containment at other fuel storage locations around the island
- Ban pig farming in areas close to the lagoon shore
- Consider relocation of septic tank fields to ocean side of the atoll. Practically this may be difficult to implement given most of the residences are located on the lagoon side of the atoll. Community discharge fields may be an option worth considering

Recommendations for Further Environmental Studies

The water chemistry and vertical mixing is not understood and needs to be investigated so that potential risks (through algae blooms or further nutrient enrichment) can be better understood. This should include:

- Depth profiling (nutrients and physio-chemical parameters) to the lagoon floor including the deepest parts of the lagoon. This needs to be undertaken over an extending period and seasonal variations;
- Nutrient content of sediment pore water in the deeper areas should be studied to better understand nutrient flux in the lagoon.
- Lagoon flushing needs to be better understood as it may affect the sustainable limits of the lagoon.

Monitoring Programme Improvement and Capacity Building

The monitoring programme needs to be improved to include depth profiling of the water column (nitrate / nitrite, ammoniacal-amongst other nutrients are likely to be most concentrated near the sea floor).

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1. Introduction

1.1 Background

The Ministry of Marine Resources of the Cook Islands (MMR) have engaged GHD Limited (GHD) to undertake an Environmental Impact Assessment of discarded pearl farming equipment and other related debris within Manihiki Lagoon, and a Feasibility/Cost Benefit Study into the removal and disposal of any significant pollutants (the environmental assessment).

Pearl farming has been an important aspect of livelihood of the Manihiki community since the Early 1980's. There was significant expansion in the pearl farming industry in the 1990's. Cyclone Martin had a serious deleterious effect on the pearl farming industry on Manihiki and many people never returned to the island. Despite this, production and total sales (NZD$18M) of pearls peaked in 2000. Ever since then, the production and sales have declined through disease out breaks, lower production rates, and declining pearl quality. Currently, the number of cultured shells is in the order of 940,000 shells[1] (460,000 spat and 480,000 cultured adult oysters), and with a value of NZD $3.5m[2] in pearl sales.

MMR, in agreement with New Zealand Ministry of Foreign Affairs and Trade (MFAT), have commissioned this environmental assessment to assess the feasibility of removing of derelict pearl farming equipment within the lagoon, with the longer term view to revitalise the Manihiki Pearl industry, and create jobs and improve community wellbeing.

1.2 Project Objectives

The objectives of the project include:

- Assessment of the environmental impact of removing discarded farming equipment from the lagoon;
- Feasibility / cost benefit analysis of removing and disposing of the farming equipment;
- If required, identify a preferred methodology for lagoon clean up that can be implemented in a safe, fiscally viable and ecologically sensitive manner.

The overall goal of the project is to revitalise the pearl industry on Manihiki to improve the livelihood of the community.

1.3 Purpose of this report

The purpose of this report is to inform MMR and MFAT decision making processes and to inform the prioritisation of the steps that can be takenproject priorities to revitalise the pearl industry on Manihiki.

1.4 Limitations

This report: has been prepared by GHD for the Ministry of Marine Resources and *may only be used and relied on by Ministry of Marine Resources for the purpose agreed between GHD and the Ministry of Marine Resources as set out in section 1.3 of this report.*

GHD otherwise disclaims responsibility to any person other than Ministry of Marine Resources arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

[1] Weier, T., 2014 - Manihiki Pearl Industry: 2014 Lagoon Status Report, Ministry of Marine Resources.

[2] 2013, Gross Domestic Product at Current Market Prices, by Industry. Data from Cook Islands Department of Statistics.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.5 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Ministry of Marine Resources and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The estimates calculated for the pearl farming material requiring removal within the lagoon should only be interpreted as "rough order". The assessments were undertaken by diving on derelict farming concessions over a two week window, and establishing typical configurations. Assumptions where then made with regard to materials within the concessions and calculated up. Detailed mapping surveys would be required to gain accurate volumes and weights – however time allocations and budgets did not permit detailed mapping surveys.

1.5 Assumptions

This report has been based upon the following assumptions:

- The information provided by MMR and others is true, complete and accurate;
- For the purposes of this assessment, it has been assumed that derelict farming equipment relates to the infrastructure located in the 1997 and 2011 concessions as shown on the 1997 and 2011 GIS layer provided by MMR. This excludes 1997 and 2011 concessions that overlap with currently permitted farms.
- To derive the remediation estimate, the mass of derelict infrastructure requiring removal needed to be estimated. Weight calculations were based upon typical layouts of pearl farms, and includes percentage estimates based upon field observations and surveys undertaken by MMR. There is inherent error with these calculations and should be viewed as "best guess" estimates. The only way to accurately inventory totals would be to dive the lagoon on a systematic grid and document all structures and materials observed – time and budget constraints did not allow for this. Other assumptions and uncertainties that influence the cost estimate are identified in section 5.9.

1.6 Scope of Work

The scope of work that has been completed for this assessment includes:

- Preparation of an Assessment Plan, as required by MMR;
- Preparation of Health, Safety and Environment Plan;
- Preparation of a Dive Safety Plan;
- Logistics planning;
- Preparation of GIS maps with current and historic concessions, and bathometry shown. This was loaded on to an iPad® for ease of lagoon navigation to concessions, note taking and measuring;
- Discussions with key stakeholder groups;

- Lagoon surveys of abandoned and operating pearl farms;
- Weighing typical derelict farming equipment and associated biofouling;
- Removal of selected derelict farming equipment (one location only) to test potential environmental / lagoon impacts;
- Visit to kaoa[3] to understand seeding and other operations that occur on kaoas;
- Reef flat inspection
- Outer reef inspection
- Inspecting land based activities that may be impacting lagoon water quality
- Review of pearl farming practices, monitoring, compliance and enforcement;
- Review of existing water quality data;
- Review of documents provided by MMR;
- Review of third party scientific papers and other publications;
- Assessing the need for lagoon clean up and removal of the derelict farming equipment;
- Review of potential clean up options;
- Determining the most appropriate methodology;
- Assessing the cost and benefits of the preferred clean-up methodology;
- Preparation of this report.

1.7 Acknowledgements

This project was made possible with the assistance from the Ministry of Marine Resources, Royal New Zealand Airforce, New Zealand Ministry of Foreign Affairs and Trade, and National Environmental Service.

The insights gained from discussions with the Cook Islands Pearl Authority, Manihiki Pearl Farmers Association, Manihiki Island Council and New Zealand Ministry of Foreign Affairs and Trade in Rarotonga were very useful and findings have been included in this report.

A special thanks to Tangi Napara, Wireless Pupuke, Teinaki Maui Tairea, Ravengakore Tuteru and Nimeti Nimeti for assisting with the field work programme, and providing insight into life and pearl farming on Manihiki. The hospitality and companionship was also much appreciated.

Ben Ponia, Georgia Langdon, Dorothy Solomona, Teuru Passfield, Teariki Rongo provided excellent information and working knowledge of pearl farm operations on Manihiki, and the challenges faced by the pearl farming industry as a whole.

Joseph Mayhew and Steven Barrett from the New Zealand Ministry of Foreign Affairs and Trade in Rarotonga provided their own views and desire to revitalise the pearl industry on Manihiki in a sustainable manner. The assistance with transport to Manihiki was much appreciated.

The island councillors: Ngamata Napara (Mayor), John MacLeod, Pepe Makira, Toka Toka, Luka Kaitara (Deputy Mayor), Kumi Raipata, Pepe Makira, Justine Williams, Jane Kainea (Executive Officer) provided frank and meaningful discussions regarding the management and regulation of the Manihiki pearl industry and challenges posed with enforcement.

[3] Rocky coral pinnacle within the lagoon. Typically these have seeding houses on them.

Erina Korohina and Peter Tierney from Ministry of Finance and Management - Development Division provided useful information on the pearl industry as a whole, the economics and how aid funding may support the revitalisation of the industry.

Thanks also to Tina Brown and Terai McFadzien (Cook Islands Pearl Authority) for providing information and discussion on the Manihiki Pearl Industry.

The members of Manihiki Pearl Farmers Association including Helen McKenzie, Justine Williams, Brendon Kainea, Rick Williams, Pikitika Tepaano, John Junior Koteka, Temu Okotai shared their challenges and aspirations.

Gerald McCormack from Cook Islands Natural Heritage Trust shared the limited information and knowledge that was available on the ecology of Manihiki.

Taggy Tangimetua from the Department of Statistics provided important information of Manihiki demography and GDP contributions from pearl sales.

And lastly, Nancy Kora, Kora Kora and Tommy Kora for their excellent hospitality and companionship, and also their own views and experiences of the Manihiki pearl industry.

2. Condition of Manihiki Lagoon

2.1 Introduction

This section provides a summary of the condition of Manihiki Lagoon and other factors that potentially impact lagoon physical condition / pearl farming. This information has been compiled through discussion with stakeholders, review of data and information provided by MMR, literature review from third party sources, and field assessments undertaken by the project team.

2.2 Geographical Setting

Manihiki Island is located in the Northern Group of the Cook Islands, located approximately 650 nautical miles north of Rarotonga. Neighbouring islands included Rakahunga to the north and Penhryn to the north east.

Manihiki is a triangular shaped atoll, comprising two main islands, and a number of smaller islets on the reef flats that complete the atoll ring. It is thought that the two main islands Tauhunu and Ngake Ta Pae Roa e Tukao are both underlain by phosphatic limestone, probably of Pleistocene age[4]. Sesimic studies undertaken by Hochstein in 1965[5] indicates that 30 to 500 m of limestone overlays about 100 m of vesicular basalt.

Within the lagoon there are numerous coral pinnacles (‘Kaoas’ for those breaching the surface, ‘rorokkas’ for those below the water surface) that rise sharply from the lagoon floor. In between the kaoas / rorokkas, there are often deep depressions up to 75 m.

The lagoon is 4,461 Ha, of which 2,860 Ha would be suitable for cultured pearl farming. Water temperatures range from 27-30°C, with lagoonal waters generally 2-3 C warmer than the surrounding oceanic water.

There are three main areas of shallow entrances to the lagoon, with two larger entrances over the reef flat located on the southern side of the island, and one smaller entrance on the north eastern portion of the site. The eastern entrance in the south is approximately 4.5km across, and the western entrance in the south is approximately 4.75 km separated in the middle by Porea Island with numerous islets scattered across the entrance. The northern entrance (Aria Poto and Aria Roa) is approximately 3.5 km across with Muri Island located on the southern portion of the entrance. Water flow across these entrances is heavily impeded by limestone conglomerate rampants. An example of the rampant is shown in the photo below (plate1).

Plate 1 Example reef flats and rampants

[4] Wood, B. L. 1967 - Geology of the Cook Islands, New Zealand Journal of Geology and Geophysics, 10:6, 1429-1445.
[5] Hochstein, M.P. 1967 - Seismic measurements in the Cook Islands, South-west, Pacific Ocean, New Zealand Journal of Geology and Geophysics, v. 10: 1499-1526.

2.3 Community Setting and Demographics

There are approximately 190 residents (238 on official 2011 census) on Manihiki, and most are of Manihiki descent or from nearby islands. The population of the island peaked prior to Cyclone Martin in 1997 where the population was reported to be in excess of 700 people. A lot of people left the island during and after the storm and never returned. The population has continued to decline with people leaving the island / Cook Islands in search of work. This has meant that there has been a decline in labour force and this in turn has made the management of pearl farming operations difficult.

Table 1 below provides a summary of the 2011 census relating to vocations on the island. It would appear that only 23 people in 2011 were directly employed in the pearl industry. This would not likely take into account managers and professionals that may be employed in the industry but not categorised under fisheries workers.

Manihiki Total Working Population >15 Years old	Legislators and Senior Officials	Corporate and General Managers	Professionals	Technicians & Associate Professionals	Clerks	Service Workers, Shop & Sales Workers	Skilled Agricultural & Fishery Workers	Craft & Related Trade Workers	Plant & Machine Operators & Assemblers	Elementary Occupations
102	3	19	17	6	4	5	23	4	6	15

Table 1 Vocations of working population on Manihiki (Source: Cook Island Census 2011)

Discussions with Manihiki Pearl Farmers Association[6] (MPFA) identified that labour shortages represent a significant barrier to the operation (and also compliance) of pearl farms. There is also a lack of willingness by locals to work on pearl farms. It is understood that MMR are working with MPFA and the Ministry of Internal Affairs to source suitably qualified workers (with diving credentials) from outside of the Cook Islands including China, Kiribati and Fiji.

2.3.1 Governance

The island is administered by a democratically elected council, comprising a mayor and 6 councillors (including deputy mayor and executive officer). The island council have the responsibility for administration and control of island affairs. This includes the issuing and enforcement of pearl farming permits. 2015 is an election year for the local council,

2.4 Pearl Farming in Manihiki Lagoon

2.4.1 Manihiki Pearl Farming Regulation

The operations of pearl farming in Manihiki lagoon is determined by *The Manihiki Pearl Farming Management Plan* 2006 – 2016 (the Plan) and the *Code of Practice for Responsible Pearl Farming in Manihiki Lagoon (The Code).* The wider statutory context for this project is discussed further in Section 4.

Pearl farmers have to apply to the Island Council (5 year validity) for a permit to farm. Certain criteria have to be met in order for a permit to be granted. It is understood that a new permit with stricter conditions will be rolled out for the March 2015 permit renewal period. At the time of writing this was under legal review. It is understood that only farmers that have harvested or seeded in the last 18 months will be eligible for a new permit. If this condition is strictly

[6] Personal communication: Kora Kora, Manihiki Pearl Farmers Association, 31 January 2015.

enforced, it will mean that the “inactive” pearl farms identified in Table 2 below will not be renewed.

Compliance against the Plan, the Code, and permits are monitored by MMR, but permits are issued and enforced by the Island Council. The Council have not undertaken any enforcement over the last 5 years under the permit system, with the exception of discussions with farmers to encourage compliance.

One of the permit conditions is that any unused pearl farming equipment must be removed from the lagoon.

The monitoring against the Plan and the Code by MMR staff appears to be well documented. In a 2014 MMR monitoring report[7] it shows a high level of non-compliance with 70% of farmers and 52% of the permitted areas not meeting the required standards / permit conditions.

The non-compliance appears to largely be a result of ineffective enforcement by the Island Council. Societal pressures of this small community are likely to be a significant barrier to effective enforcement by Council.

2.4.2 Overview of Pearl Farming Operations

The typical configuration of the Manihiki pearl farm comprises a series of 12 mm diameter, 220 m long parallel rope lines that are generally tied off on remanent coral on the lagoon floor. For the deeper areas, concrete filled 25L plastic containers are used as anchors. These are lowered to the sea floor by the anchor rope.

Plastic floats are used to keep the lines buoyed at the appropriate level in the water column. Off the main lines, will be hung either spat collectors[8] (required to be 0.5 m long at 0.5 m spacing), or chaplets[9] (required to be the 1 m long at 1 meter spacing), typically 6 mm in diameter. Generally lines were arranged in parallel rows.

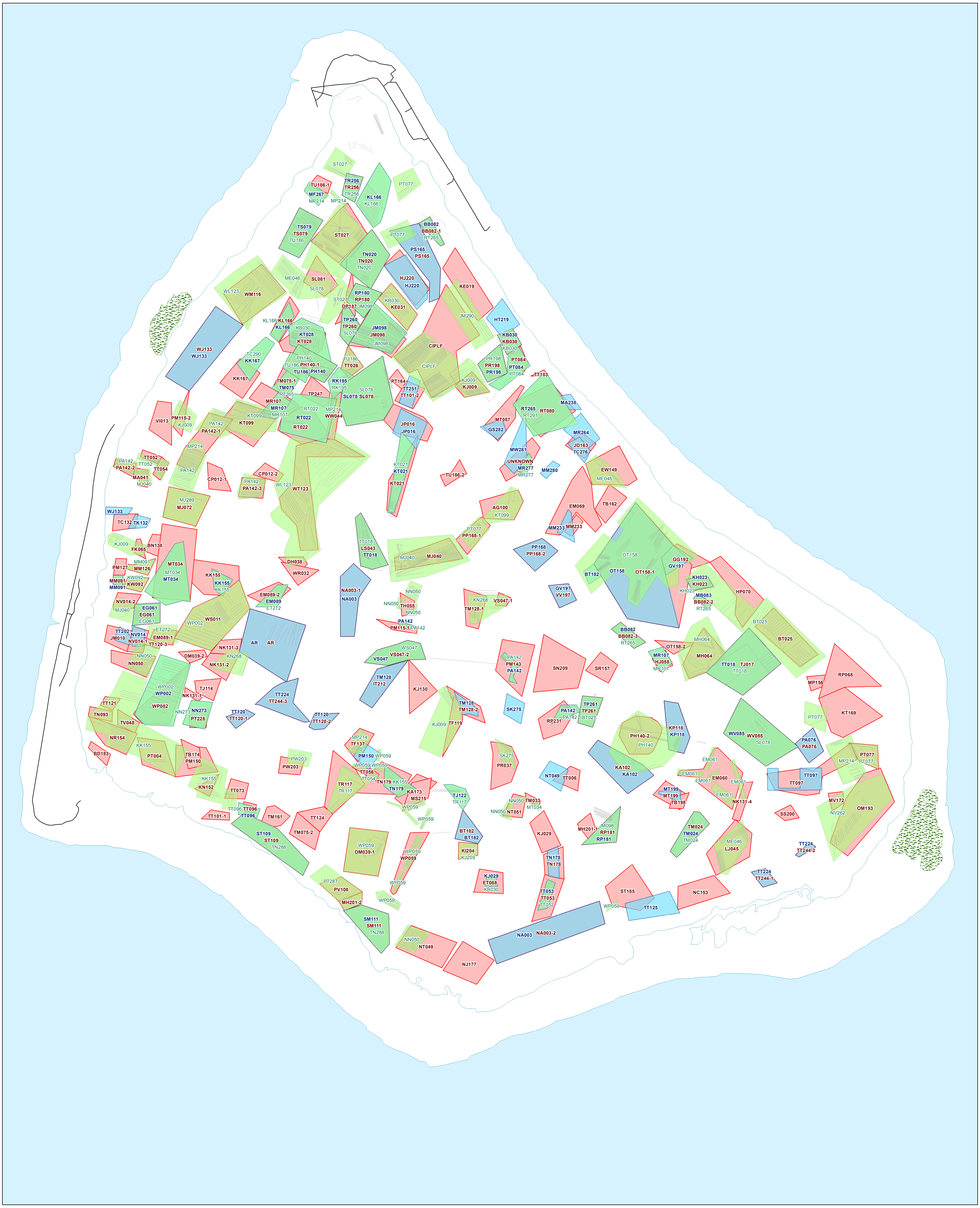
Variations of permitted farm layouts and materials were observed during field inspections, however many were not compliant with the Code. Variations included a matrix type pattern and an umbrella pattern, with mainlines radiating out from a central leader. Also minor non-compliances were observed including insufficient mainline spacing or chaplet spacing.

The farming operations begin with spat collection, which involves the collection of oyster spat on fibrous collectors. These are allowed to grow to a certain size and then the spat line is thinned and potential seeding oysters are selected. Once selected these “virgin shells” (never seeded) are hung on caplets to allow them to mature to an optimum seeding size. Once the oysters reach the correct size, they are seeded using a round nucleus made from Mississippi mussel shell and mantle from an oyster selected for its ideal colour and shell nacre. The seed and mantle are inserted into the gonad by a specialist pearl seeding technician. Once seeded the shells are returned to the chaplets, and harvested 18 months later. During this 18 months period, the shells are required to be cleaned to ensure that the quality of the pearl is maintained.

At the time of harvest the pearl is removed, and the oyster is either reseed (upto 3 reseedings) or terminated. The lagoon management plan requires that discarded oysters are disposed on land and not in the lagoon. Significant piles of discarded shells were observed on a number of kaoa adjacent to the seeding houses suggesting that this practice is not strictly followed and would contribute to lagoon nutrient loading.

The current (2012). 2011, and 1997 concession areas are shown in Figure 1.

[7] Weier, T. August 2014: Manihiki Pearl Industry: 2014 Lagoon Status Report.
[8] Used to collect and grow new stock oysters
[9] Used for suspending virgin or seeded oysters in the water column



LEGEND

Farm 2012	Lines Complete 2014
Farm 2011	Roads
Farm 1997	Vegetation
Island Outline	

Paper Size A1

0 0.2 0.4 0.6 0.8 1

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: WGS 1984
Grid: WGS 1984 UTM Zone 4S

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Ministry of Marine Resources, Cook Islands
Manihiki Lagoon Black Pearl Strategic Environmental Assessment

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Pearl Farm Areas: 1997, 2011 and 2012

Figure 1

G:\51\32979\GIS\Maps\Mxd\5132979_G001_RevA_Figure 1_Pearl Farm Areas.mxd

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Data source: MMR: Farm areas - Feb 2015. Created by:jhchen

The summary table below provides an overview of the current farming operations on Manihiki:

Type	Number of Currently Permitted Farmers (All Permits Expire in March 2015)	Number of Concessions	Area Covered by Concessions (Ha)
Active Permitted	22	62	602
Active Permitted Hobbyist Farmers	2	3	27
Inactive (Abandoned but currently permitted)	42	71	585
Historically abandoned and not replaced by new concession	Not Applicable	64[10]	610[11]

Table 2 Summary of currently permitted farming operations (Source: MMR Manihiki Records 2015 unless otherwise stated)

Given the lowering of the global pearl price, there has been a need to drive cost savings and increase efficiency[12]. This has meant that a lot of the smaller pearl farming operations are no longer profitable (and hence abandoned). Larger farms have been developed improve returns. The graph below demonstrates this shift to larger concession areas over the years.

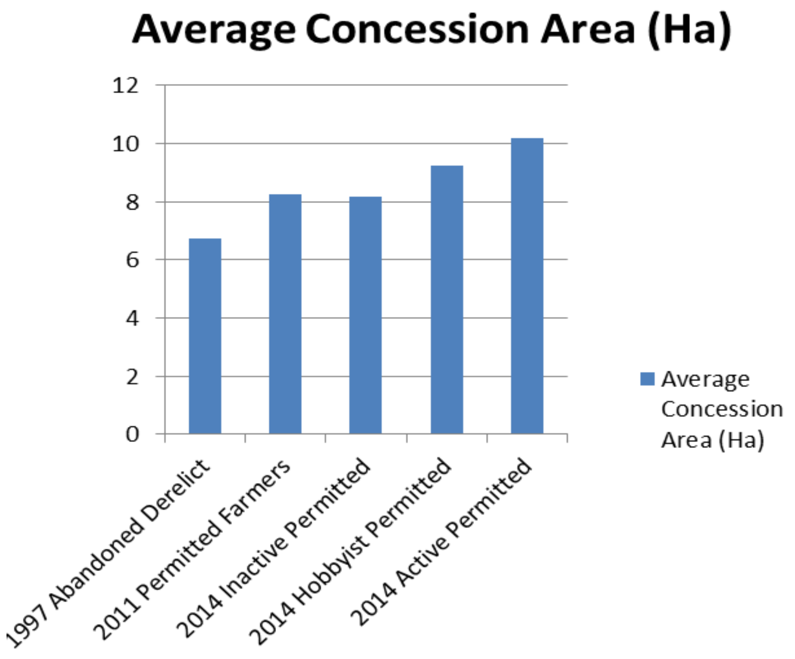

Figure 2 Average concession size increase over time.

[10] Approximate only - Tally from GIS maps of lapsed 1997 permits not currently permitted. Some abandoned farms were not historically permitted and as such not shown on GIS Layers.
[11] Weier, T. November 2013: Proposal for Works - Clean-up of the Manihiki Lagoon, MMR.
[12] Pers. Comm Kora Kora, Manihiki Pearl Farmers Assocaition, 2nd Febraury 2014.

2.4.3 Lagoon Pearl Farm Carrying Capacity

Reports prepared by RDA in 1997[13] estimated the number of oysters in the lagoon to be 13 million in 1997, with a 1998 projection of 18 million. The table below provides a summary of the breakdown of the oyster count. The wild oyster count was undertaken using transect and grid counting.

Type of oyster	Count (Million)	Sustainable Level Count
Wild oysters	3.14	3.14
Hanging farmed oysters	1.09	1.0
Discarded used oysters	1.09	1.0
Spat on collectors	8	3.0
Total	**13.23**	**8.0**

Table 3 Number of oysters in the lagoon in 1997 (Source: RDA 1997)

The 2014 MMR stock survey report[14] identified that in 2014, there were approximately 460,000 spat and 480,000 hanging farmed oysters in the lagoon in currently permitted areas. This survey is likely to be more accurate than previous census undertaken by MMR as it involved inspecting the lines rather than relying on farmers advising how many shells they were farming.

This survey however did not consider live discarded oysters, or oysters on abandoned farming equipment.

The 1997 RDA report (Refer table 3 above) puts the sustainable farming levels of pearl shells at around 5 million shells, which comprises 1 million hanging shells, 3 million on spat collectors and 1 million discarded shells.

On face value, the 2014 MMR stock survey report appears to show that pearl farms were well below the sustainable carrying capacity of the lagoon. However, the statistics may be misleading as it does not account for discarded shells beneath permitted farms. Furthermore, observations made by GHD during this investigation has shown that discarded oysters beneath abandoned farms may be significantly higher than in other areas of the lagoon, and also many abandoned farms contain chaplets and spat collectors with live oysters. This additional oyster stock has not been accounted for in the census.

The current permitting system also does not appear to have any “safety checks” for stocking densities – that is permits could be allocated to above sustainable farming limits.

2.4.4 Abandonment of Pearl Farm Infrastructure

The reason for abandonment is varied, but the two primary reasons commonly given is the departure of people from Manihiki during and after Cyclone Martin (November 1997) and that the decline in the pearl price has meant that the farming (in particular the smaller farms) was no longer profitable. Generally, the derelict concession areas are smaller than the currently permitted farms (see Figure 1 above).

The derelict farming equipment is in the lagoon due to lack of farmer compliance with permit conditions and lack of enforcement by Council. For the pearl farmers that have left Manihiki and abandoned their farms, enforcement has become very difficult, and there is no bond on those

[13] RDA International Inc, (1997) Final Report: Lagoon Ecology Monitoring and Management Project, Manihiki Lagoon, Cook Islands.

[14] Weier, T., (2014) Manihiki Pearl Industry: 2014 Lagoon Status Report August 2014. Ministry of Marine Resources.

operators to provide either an incentive for them to clean up their farms or provide funds for this work to be managed by council.

The configuration of the abandoned farms is similar to that of current active farms with parallel configurations dominating. The derelict farms are dominated by:

- Floats at surface (not permitted due to navigational hazard) due to snapped anchor lines;
- Sunken lines due to separation of floats from the mainlines;
- Approximately 65% of the derelict farms inspected had chaplets or spat collectors attached to mainlines where lines were still buoyant in the water column;
- Heavy biofouling of areas located over deeper water (>10m) of lines and floats, comprising bivalves, sponges, soft corals, anemones, and clams (amongst other organisms). It should be noted that the biofouling observed on derelict farms was no different to poorly maintained active farming areas;
- Light biofouling in lines located in shallow water;
- Significant numbers of discarded / dropped live oysters underneath historic lines;
- Underwater spat sorting platforms made of PVC piping and plastic matting was noted at 2 locations;
- 25 L float drums were noted at some locations.
- All observed derelict farming areas were anchored to the coral on the lagoon floor.
- At one location, a kaoa spat sorting platform had collapsed into the sea. This included corrugated super-six asbestos roof sheeting.

Examples of the types of derelict farming equipment observed and associated photographic log is included in Appendix A.

2.4.5 Perceived Family Entitlement to Historic Concession Areas

There is a perception with some people in the Manihiki community that there is perceived family entitlement to specific areas (often relating to historically assigned concession areas) of the lagoon, in that an area is “owned” by the family[15], even though the family may be currently pearl farming, or may not be even present on the island.

Nimeti Nimeti (Environmental Officer – National Environmental Service) mentioned[16] that perception may be linked to tribal periods of the past when the lagoon was split up into 12 family areas.

Under Cook Islands law the lagoon and sea bed are owned by the government and as such personal ownership does not exist.

This perception may cause a barrier to those wishing to expand their existing pearl farms or for those that are starting out. The Council requires that any farmer wishing to take over an area that has been historically permitted is required to seek permission from the family that historically held the concession for the particular area. Often permission is not granted as the family wishes to “hold” the area in the event that they wish to re-enter pearl farming or to preserve the area for future generations. In some cases, the families no longer live on Manihiki or in the Cook Islands. These areas also generally contain abandoned equipment.

[15] Pers. Comm Ngamata Napara (Manihiki Mayor) 29th of January 2015.
[16] Pers. Comm Nimeti Nimeti (Manihiki Environmental Officer – National Environmental Service) 7th February 2015.

2.5 Lagoon Hydrology and Flushing

Consideration of lagoon hydrology and flushing is important to consider when assessing lagoon health. A number of studies (Soloman 1996, 1997[17], Callaghan *et al.* 2006[18]) have been undertaken on flushing and water circulation within Manihiki Lagoon.

Discussions with MMR[19] have indicated that there is some thought that the derelict farming equipment may be impeding the flow of water in the lagoon and therefore increasing residence time of the water leading to degradation of water quality. Whilst it may be true that the abandoned oyster farms could impede water movement, we do not believe that this would be a significant contributing factor to influence water quality.

We consider that the flushing rate (62 days) proposed by Callaghan *et al.* is unlikely, as the study assumes (theoretically) that full vertical mixing occurs. Field studies undertaken as part of the Soloman study shows that there is clear stratification and that full mixing does not occur. This is supported further by the depth profiling of temperature and salinity undertaken as part of the routine water quality monitoring undertaken by MMR for Manihiki Lagoon.

The flushing rate is an important aspect to consider when assessing the sustainable carrying capacity for the lagoon for pearl oyster culture. Increased residence time negatively impacts water quality. We believe this warrants further assessment to better understand lagoon carrying capacity - recommendations are covered in section 6.

2.6 Impact of Land Based Activities on the Lagoon

A survey was undertaken of land based activities that have the potential to impact the health of the lagoon. The main activities that were identified include:

- Septic tanks
- Open rubbish pits
- Disposal of biofouling waste
- Pig farming
- Fuel storage for diesel generators
- General fuel storage for vehicles and boats.

Septic tanks, pig farming, and biofoulant waste disposal would contribute to lagoon nutrient loading. The soils of the island (coral sands and gravel) would have a high hydraulic conductivity, meaning that any groundwater would move relatively quickly, and as such any nutrients would end up in the lagoon (or ocean) in a relatively short period of type. Testing of community groundwater wells shows that most are contaminated with faecal bacteria, likely from septic tanks. This also indicates that groundwater in the villages or Tukao and Tuahunu would be expected to have relatively high nutrient concentrations. The nutrient loading from septic tanks, pig farming and biofoulant disposal, is likely to have some impact on the lagoon, however to a large extent there a limited practical alternatives to these current activities.

The rubbish pits observed contained generally domestic waste, end of life durable goods and coconut husks. Burning of waste materials appears to be a common practice to reduce the volume of waste materials. These unlined pits appear to interface with groundwater, based upon groundwater elevations observed in domestic wells. As such, are likely to be a source of groundwater contamination including microbial, nutrient, metals, hydrocarbons, and semi-volatile organic compounds. As with the septic tanks, contaminants would be expected to

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[17] Soloman, S. (1997) Circulation Studies in Manihiki Lagoon, *SOPAC Technical Report 246*

[18] Callaghan, D.P., Nielsen P., Cartwright, N. Gourlay, M., Baldock, T.E. (2006) Atoll lagoon flushing forced by waves, Coastal Engineering 53691–704

[19] Pers. Comm - Bon Ponia, Secretary of Marine Resources, 27th of January 2015.

readily discharge to the lagoon or ocean side reef. The contribution / mass of contaminants is not considered to be significant or of concern for lagoon water quality.

Whilst land based fuel storage does not pose a risk to the lagoon from normal day to day operations, it may pose a significant risk in the event of significant fuel loss or spillage. All of the fuel storage observed, did not have secondary containment in the event of fuel loss. This could be easily be remedied by constructing a concrete bund using locally available materials.

2.7 Nutrient Enrichment of Lagoonal Water

Anecdotal evidence, obtained through discussion with village elders, suggests that lagoon health began a noticeable decline in the early to mid-1980s. This timeframe coincided with the development of the pearl industry. The changes that were most noticeable to the community were the loss of coral within the lagoon, disappearance of large schooling fish such as trevally, and also hapuku (Marbled Grouper - *Epinephelus polyphekadion*). The condition of the lagoon persists today, as evidenced by the field surveys undertaken as part of this assessment, and also described further in section 2.7 in this report.

Coral is particularly sensitive to nutrient enrichment[20], and generally only thrives in oligotrophic (nutrient poor) conditions. The loss of coral within the lagoon may be linked to increased nutrient levels in lagoonal waters.

The coral communities on the outer reef appear to be healthy and diverse, and therefore it appears that the issue of water quality decline is only manifesting itself within the lagoon.

A study undertaken recently in French Polynesia[21] shows that cultured pearl oysters and associated biofouling can have a significant contribution to nutrient cycling in closed oligotrophic lagoonal systems. The cultured pearl oysters with biofouling contributed 4-6 times more nutrients than clean cultured oysters. It was estimated that one line of chaplets (i.e. nutrients from excretion of the oysters on the chaplets) may contribute as much as 70% of the nutrients for primary production required to feed the oysters, with biofouling contributing up to 60% of the nutrients released. It concludes that pearl culture enhances nutrient availability within the local environment of the farm, altering the natural balance in the ecosystem.

A comparable study[22] undertaken in New Zealand undertaken on mussel farms, shows that cultured bivalves also enhance nitrogen mineralisation and cause nutrient enrichment of the benthic environment. That study also observed a decline in health of the benthic environment associated with the farm and a shift in biota to a community dominated by polychaetes (marine worms).

In summary, it appears that the farming of black lipped pearl oysters has lead to a decline in water quality since the intensification of the pearl farming industry in the early 1980's, manly through biofouling and the increased nutrient load produced by the farming operations.

2.8 Water Quality

MMR has been undertaking water quality monitoring of lagoon water since 2006, with weekly monitoring commencing in 2012. The period between monitoring events appears to be inconsistent, and as such the data set cannot be considered seasonally representative since 2006. The monitoring is supposed to be undertaken from set locations within the lagoon, on a

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[20] Bell, P. R. F. (1992). Eutrophication and coral reefs—some examples in the Great Barrier Reef lagoon. Water Research, 26(5), 553-568.

[21] Lacoste, E., Gueguen Y., Le Moullac G., Koua S., Gaertner-Mazouni N. (2014) Influence of farmed pearl oysters and associated biofouling communities on nutrient regeneration in lagoons of French Polynesia. Aquaculture Environment Interactions. Vol. 5: 209–219, 2014

[22] Kaspar, H. F., Gillespie, P. A., Boyer, I. C., & MacKenzie, A. L. (1985). Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. Marine biology, 85(2), 127-136.

weekly basis (field parameters of pH, electrical conductivity, dissolved oxygen, salinity) with sampling of water for laboratory analysis every fortnight to coincide with commercial flights back to Rarotonga (location of the laboratory).

Whilst the current water quality monitoring programmes provide intermittent nutrient data back to 2006, the gaps in the data make interpretation more difficult. Furthermore the historic water quality assessments undertaken by RDA in 1997 did not include nutrient parameters, and as such historic comparisons are not possible.

It is difficult to deduce trends given the intermittent nature of the water quality data set. However it is clear that, the Dissolved Inorganic Nitrogen (DIN) to Dissolved Reactive Phosphorous (DRP) ratio is less than 16, therefore it can be considered that nitrogen is the limiting nutrient (between nitrogen and phosphorus)[23]. Based upon the evidence in the Lacoste study, it could be inferred that farmed oysters (and associated biofouling) would likely be one of the primary contributors of nitrogen in the lagoon, in addition to land based activities.

The *Water Quality Guidelines for the Great Barrier Reef Marine Park*[24] *(Great Barrier WQG)* is one of the few guideline documents that is available that relates to the management of marine water quality for the protection of tropical coral ecosystems. The guideline values have been derived for the protection of marine species in the Great Barrier Reef and therefore are not directly applicable to Manihiki Lagoon – but do provide a baseline value against which to compare. Comparisons show that the mean chlorophyll *a* concentration between 2006 and 2013 was slightly above the Great Barrier WQG, indicating there is an imbalance of nutrients within the lagoon which may impact the health of the some organisms in the lagoon.

Parameter	Guideline Value[25]	Mean for Manihiki Lagoon 2006-2013
Chlorophyll *a*	0.45 µg/L	0.47 µg/L

Table 4 Comparison of chlorophyll a results for Manihiki Lagoon 2006-2013

Chlorophyll *a* is widely accepted as good indicator of the nutrient status of an aquatic ecosystem. Bell[26] suggests that an appropriate indicator level for the onset of eutrophication for a comparable lagoonal coral reef system in Australia is 0.5 µg/L. This means that the mean Chlorophyll *a* concentration measured for Manihiki Lagoon up to 2013 is nearing this eutrophication onset threshold, with discrete sampling events markedly above this value.

Algae Blooms

Increases in nutrient loading changes the phytoplankton community, and in turn this changes nutrient cycling with flow on affects to the structure within the food chain[27]. Changes in nutrient status of oligotrophic coral reef waters and associated changes in phytoplankton communities are expected to more profound than those of mesotrophic or eutrophic temperate systems. Changes in phytoplankton communities have been linked increases in algae blooms[28] in

[23] Bell, P.R.F, (1992). Eutrophication and coral reefs – some examples in the Great Barrier Reef lagoon. Water Research. Vol. 26. No. pp. 553-568

[24] Open coastal water guideline values. Great Barrier Reef Marine Park Authority (2009). Water quality guidelines for the Great Barrier Reef Marine Park.
Great Barrier Reef Marine Park Authority, Townsville

[25] Great Barrier Reef Marine Park Authority (2009). Water quality guidelines for the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority, Townsville

[26] Bell, P.R.F (1991) Eutrophication and Coral Reefs – Some Examples in the Great Barrier Reef Lagoon. Department of Chemical Engineering, University of Queensland, St Lucia, Qld 4072, Australia.

[27] Sakka A, Legendre L, Gosselin M, LeBlanc B, Delesalle B, Price NM (1999) Nitrate, phosphate, and iron limitation of the phytoplankton assemblage in the lagoon of Takapoto Atoll (Tuamotu Archipelago, French Polynesia). Aquat Microb Ecol 19:149–161

[28] Jacquet Séverine, Delesalle B., Torréton Jean-Pascal, Blanchot Jean. (2006), Response of phytoplankton communities to increased anthropogenic influences (southwestern lagoon, New Caledonia). Marine Ecology Progress Series, 320, p.

temperate waters. Harmful algae blooms (HABs)[29] have been linked to anoxic conditions and changes in ecological communities.

A 1997 report[30] for Manihiki lagoon reported that local fishermen and pearl farmers often observed "Dark Periods" during winter months. This relates to periods where water quality was observed to be highly reduced. RDA noted that during a "dark period" observed in 1996 a bloom of pinnate diatoms was identified. Whilst smaller diatoms form an important part of the oyster diet, phytoplankton blooms such as the one observed in 1996 can cause irritation on the gills of oysters, and in extreme cases can reduce gas exchange over the gill membranes – stressing the oysters.

It should be noted that conditions need to be right for algae blooms to proliferate, such as water temperature, species type, available nutrients and biomass. This means that unless all these conditions prevail, then algae bloom will not be observed. Under normal oligotrophic conditions, algae blooms will not be typically observed due to insufficient nutrients.

Stratification and Vertical Mixing

Soloman[31] identified that during studies undertaken in 1996 that there was clear stratification in the lagoon with cooler more saline water apparent at 30 m depth. The thermal and saline stratification is also evident in Sharma *et al* studies[32] in 2000.

Soloman hypothesised that during cooler months (winter august/September) vertical mixing was likely to occur through thermal "turn over".

Diving undertaken as part of this project in the deeper areas of the lagoon (te ngai moraro) noted a distinctive brown layer of water from about 45m to the lagoon floor (approximately 52m to sea floor at this location). This may be indicative of nutrient rich water, however water sampling (and analysis) from these depths would be required to confirm this hypothesis.

Nutrient Flux

Given that algae blooms are observed during winter periods, this may indicate thermal inversion of lagoon water. Temperature and/or salinity changes in water can create density differences (lower temperature water / higher salinity water is denser), and therefore initiate vertical mixing in the water column. This may cause deeper, nutrient rich water to rise to the surface, potentially contributing to the risk of algae blooms. Whilst this phenomenon is well understood and studied in temperate environments, there appears to be no readily available published studies for tropical lagoons.

Figure 2 below is a plot of DIN vs temperature from water quality data collected for the lagoon. The figure shows that there appears to be a relationship between DIN and temperature – elevated DIN concentrations appear to correlate to elevated water temperatures.

[29] Are primarily caused by six algal groups (diatoms, dinoflagellates, haptophytes, raphidophytes, cyanophytes, and pelagophytes).

[30] RDA International Inc, (1997) Final Report: Lagoon Ecology Monitoring and Management Project, Manihiki Lagoon, Cook Islands.

[31] Soloman, S. (1997) Circulation studies in Manihiki Lagoon , Cook Islands. South Pacific Applied Geoscience Commission Technical Report 246.

[32] Sharma, S., Frost, G., & Smith, R. (2001). Water-quality Analysis Manihiki Lagoon, Cook Islands. South Pacific Applied Geoscience Commission. Technical report 331.

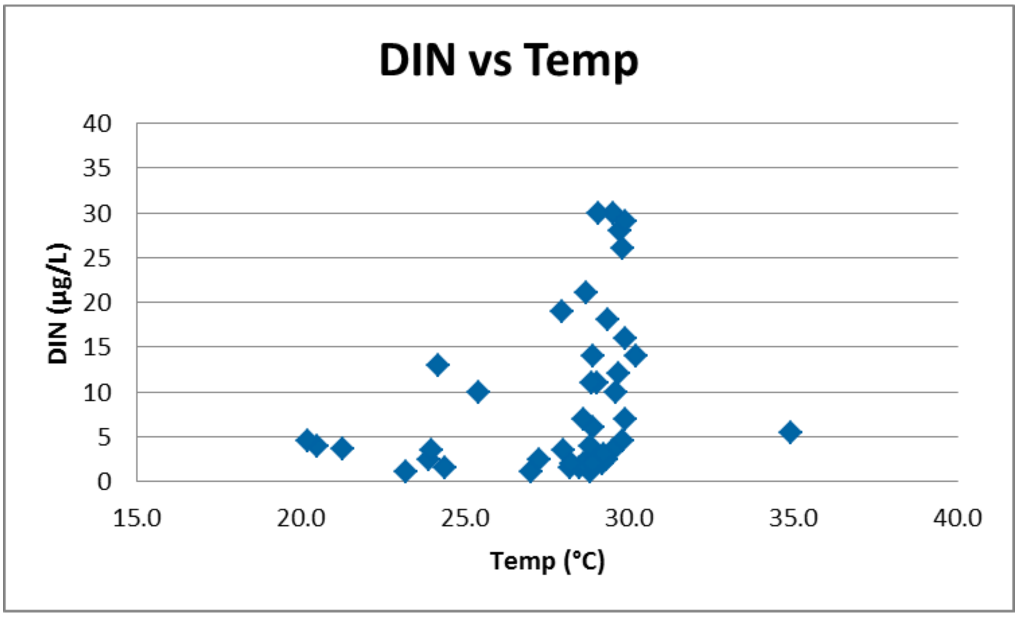


Figure 3 DIN vs Temperature

The reason nutrient enrichment is important to consider in the context of this project is that biofouling and discarded oysters and land based human activities contribute to the nitrogen loading of the lagoon, potentially increasing the risk of algae blooms, such as what was observed during the "dark periods". This may give rise to conditions that impact the farmed pearl oysters.

Impact on Pearl Production

There are limited published studies on the impact of nutrients on pearl culture / quality; the following conclusions can drawn based upon current knowledge and information reviewed as part of this project:

- Higher nutrients within the lagoon are likely to lead to higher primary production rates (growth of phytoplankton);
- Oyster growth rate is dependent on the type of phytoplankton / zooplankton availability[33][34], and may not necessarily increase oyster growth rate;
- Increase in nutrients in the lagoon alter the balance in the ecosystem and can alter the phytoplankton and zooplankton communities, which can be detrimental to oyster health;
- Increase nutrients in the system deviates from the oligotrophic (nutrient deficient) conditions to which the pearl oyster is adapted to in wild habitats.

2.9 Lagoon Ecology

2.9.1 Overview

The marine environment of Manihiki lagoon has been highly modified by the pearling industry. The following sections provide an overview of the features of the existing environment, including intertidal habitats, subtidal benthic habitats, biofouling communities, and fisheries and protected species.

[33] Martínez-Fernández, E., Acosta-Salmón, H., & Southgate, P. C. (2006). The nutritional value of seven species of tropical microalgae for black-lip pearl oyster (Pinctada margaritifera, L.) larvae. Aquaculture, 257(1), 491-503.
[34] Fournier, J., Dupuy, C., Bouvy, M., Couraudon-Réale, M., Charpy, L., Pouvreau, S., & Cochard, J. C. (2012). Pearl oysters Pinctada margaritifera grazing on natural plankton in Ahe atoll lagoon (Tuamotu archipelago, French Polynesia). Marine pollution bulletin, 65(10), 490-499.

2.9.2 Intertidal habitats

Two primary types of intertidal habitats are present at the lagoon: sandy beaches and hard substrates (Plate 2). The sandy beaches are generally less than five metres wide and are characterised by coral sands and shell rubble. In addition to the beaches that surround the greater lagoon, a more expansive intertidal inlet area is located at the north east of the lagoon. This inlet is primarily comprised of sands with some finer muds accreted at the margins.

Hard substrates comprise naturally occurring rocky intertidal areas and man-made seawalls. The seawalls are constructed from local material and vary in slope from vertical structured walls, to gently sloping boulder fields.

The tidal flux in the lagoon is in the order of 0.2 m, and the majority of intertidal habitats are truncated by a steep drop off into sub tidal waters. Therefore limited intertidal habitat is available for colonisation. Biota observed at the intertidal areas were typical of those found in tropical assemblages and included gastropods, bivalves, crustaceans and some limited macro algae.

a. **Sandy beach**

b. **Natural rocky shore**

c. **Inlet**

d. **Seawall / Kaoa**

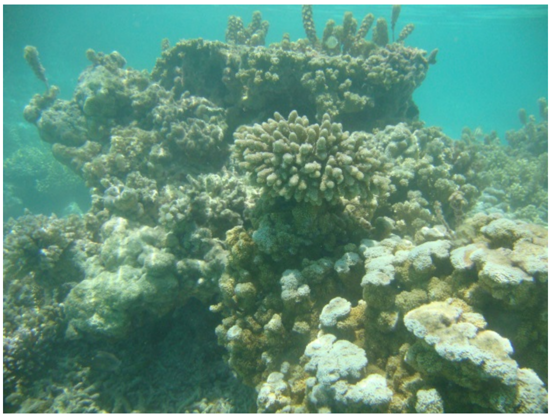
Plate 2 Example photographs of intertidal habitats

2.9.3 Subtidal benthic habitats

The naturally occurring subtidal benthic habitats that characterise Manihiki Lagoon are comprised of open sandy or muddy substrate interspersed with live and dead coral outcrops. Living reef communities are present at the southern edge of the lagoon, where the oceanic waters cross over into the lagoon (Plate 3a). The occurrence of live coral outcrops decreased in the northern reaches of the lagoon and in proximity to active and abandoned leases; at these areas dead coral were frequently observed. Anecdotal evidence (refer to Section 2.7) suggests that declines in coral health commenced with the establishment of the pearl industry in the early to mid-1980’s and population grown on the island.

Within the body of the lagoon the most diverse benthic communities are associated with the kaoas and rorokkas (Plate 3b), which provide hard substrate for organisms to colonise as well as niche areas which act as refugia for small fish, crustaceans and molluscs. Benthic cover at the coral outcrops is dominated by hard corals (digitate, branching, encrusting, mushroom, submassive and massive growth forms), soft corals, giant clams (*Tridacna spp*.; Plate 3c), and brown macroalgae (*Turbinaria ornata*).

In proximity to active and abandoned leases the benthic communities are dominated by discarded live and dead pearl oysters (*Pinctada margaritifera*) (Plate 3d), live and dead mushroom corals, and farming equipment such as discarded rope and sunken floats.



e. Reef community at southern edge of lagoon

f. Kaora coral outcrop

g. Paua / Giant clams

h. Discarded oysters

Plate 3 Example photographs of subtidal benthic habitats

Crown of Thorns Starfish

The Crown of Thorns Starfish (*Acanthaster planci*) is an invasive species that was identified to be present in Manihiki approximately three years ago. This species eats coral, and has been known to destroy large areas of coral. Some notable examples have been documented for the Great Barrier Reef.

As part of our lagoon surveys, Crown of Thorn starfish were identified within the lagoon, whereas it had previously only been identified on the outer reef. The specimen captured was thought to be 3-4 years of age due to its size.

Whilst the Crown of Thorn, has some natural predators that are present in Manihiki (various fish species and molluscs), it is still a concern for the National Environmental Service as its potential to impact on the local coral community is unknown[35].

[35] Pers. Comm. Nemeti Nemti – National Environmental Service.

Several studies [36][37][38] undertaken in Australia have linked outbreaks of Crown of Thorns to nutrient enrichment and decline of water quality. The outbreaks were attributed to an increased survivorship of Crown of Thorn Starfish larvae due to the presence of increased phytoplankton.

2.9.4 Biofouling communities

Discarded farm equipment provides hard substrate for colonisation which, in some areas of the lagoon such as open sandy substrates, would otherwise not occur. The majority of discarded equipment within the lagoon is in the form of submerged floats and lines at various depths in the water column, in various states of disuse and disrepair. Biofouling communities are those assemblages that colonise the discarded equipment .

There were distinct patterns observed in the biofouling communities relating to the depth at which the equipment was suspended, the depth of the overall water column, and proximity to active farms. Equipment suspended within 10 m of the water surface had a higher coverage of biofouling than that suspended at greater depths. Similarly, equipment suspended over deeper waters and/or in proximity to active farms was observed to be more fouled than that suspended over shallow waters and/or distal to active farms .

The biofouling communities observed to be colonising the disused farming equipment were typically comprised of colonial ascidians, anemones, sponges and bryozoa (Plate 4). Often these organisms were growing as secondary cover over pearl oysters and other large bivalves. These communities were distinct from the coral and other assemblages observed in the natural environs of the lagoon, as described in previous sections.

[36] Brodie J and Mitchell A (2005). Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments. Marine and Freshwater Research 56(3):279-302.

[37] Brodie, J., Fabricius, K., De'ath, G., & Okaji, K. (2005). Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. Marine Pollution Bulletin, 51(1), 266-278.

[38] Fabricius, K. E., Okaji, K., & De'ath, G. (2010). Three lines of evidence to link outbreaks of the crown-of-thorns seastar Acanthaster planci to the release of larval food limitation. Coral Reefs, 29(3), 593-605.

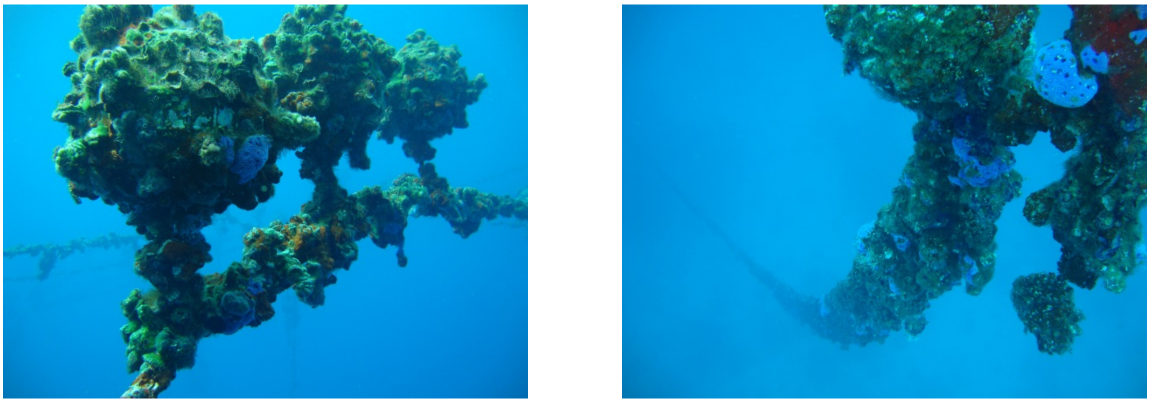


Plate 4 Example photographs of biofouling communities

2.9.5 Fisheries and protected species

Limited artisanal fishing practices occur within the lagoon. Milkfish (*Chanos chanos*) is actively harvested from the inlet at the north east of the lagoon, and from a ponded area on the Porea islet. Schools of pelagic fish, such as trevally (family *Caragidae*) and bonefish (family *Albulidae*), are common within the lagoon, as are higher order predators such as reef sharks (family *Carcharhinidae*). However, the majority of fishing effort is undertaken outside the lagoon as this is regarded as a more productive environment.

Protected turtle species have been observed using the lagoon for feeding and the surrounding ocean beaches for nesting. Species include green turtles (*Chelonia mydas*) listed as Endangered on the IUCN redlist, and Hawksbill turtles (*Eretmochelys imbricata*) listed as Critically endangered on the IUCN redlist. Given the presence of globally significant populations of seabirds at other islands within the Cooks (e.g. red-tailed tropic birds on Takutea), it is likely that Manihiki is also overflown and/or utilised by seabirds such as tropic birds, boobies, frigatebirds, noddies and terns, including those protected under international legislation .

3. Lagoon Clean-up Feasibility and Impact Assessment

3.1 Primary Issues

Whilst the scope of the project is to assess the need for the removal of derelict farming equipment from the lagoon, and assess potential impact of land based activities on the lagoon, it is important to consider wider contributing factors that have influenced the current condition of the lagoon and the reason for the derelict equipment in the lagoon. This section summarises the primary issues that need to be addressed in order to improve overall health of the lagoon to improve long term sustainability of the pearl farming industry.

The primary issues that contribute to abandonment of pearl farming equipment and poor lagoon health include:

- Current enforcement regime by council for non-compliant current permitted farms is ineffective, leading to increased stock densities and sub-optimal farming conditions;
- Lack of enforcement means that the abandonment of equipment may occur again in the future;
- Permits reportedly all expire in March 2015. It is likely that inactive currently permitted farms will also be abandoned.
- Departure of families from the island has contributed to the abandonment of pearl farming equipment;
- Insufficient labour force to undertake the required work, which potentially leads to further abandonment of equipment.
- Discarded live oysters beneath abandoned farm infrastructure (and also permitted farms) appear not to have been considered in lagoon carrying capacity calculations / stock census, therefore stock levels may be well under estimated.
- Discarded live oysters (beneath permitted and abandoned farms) are likely to be a significant contributor of nitrogen in the lagoon, therefore impacting water quality;
- Biofoulant on abandoned and permitted farms are likely to be contributing to nutrient loading of lagoon water;
- Floats at surface from abandoned farms pose a navigational hazard.

3.2 Observations of Test Removal of Derelict Pearl Farming Gear

GHD with MMR undertook removal of some selected pearl farming equipment (see photo log Appendix A) in order to test what environmental impacts might be in the event of a full scale removal project. The removal of the equipment was undertaken on a fine, calm day, in water depth ranging from 20 to 28 m. A video clip of the removal of a chaplet line can be found here: http://www.ghd.com/video/black-pearl-oysters-sea-bed/index.html.

The process of the removal included cutting the anchor ropes from the coral (dead coral) on the lagoon floor, cutting main lines at discrete intervals to ease handling, collection into a bulk back in the boat, return to shore for sorting, recovery of the floats, disposal of the chaplets, spat collectors, ropes, biofoulant, and oysters into a rubbish pit. On full scale removal, this process might be changed slightly to suit. The discarded shells may also have some residual value for arts, crafts and button making, and therefore would likely be saved for onsale.

The key observations noted from this removal of the equipment included:

- Limited disturbance of lagoon floor sediments;
- Minimal disturbance of coral flora and fauna;
- Some limited loss of apparent biogenous and lagoon sediment when lifting lines up through the water column;
- Some limited loss of biofoul material into the water column;
- At this location, the limited number of discarded shells did not warrant retrieval; and

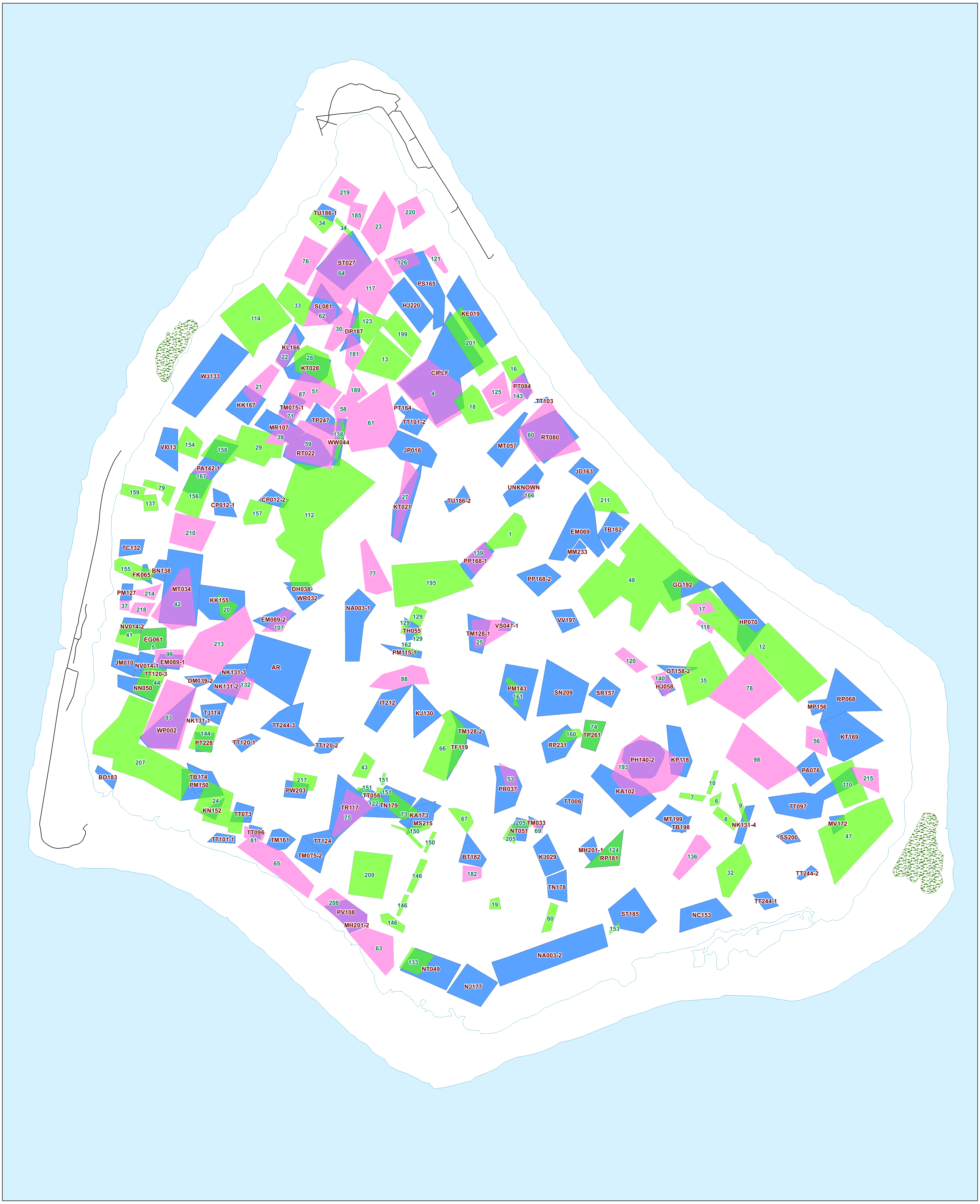
Overall no notable impacts were observed during the removal of the equipment. Whilst impacts were noted to be minimal, the compounding factor of removing a number of derelict farms over a short period may have some impact. This risk can be minimised through a carefully managing and staging the works, and also through implementing water quality monitoring programmes prior to and during the removal works. This will monitor changes in water quality changes and contingency measures can be put in place to mitigate or minimise risk.

3.3 Quantification of Debris Required to be Removed

The primary debris that needs to be removed from the lagoon includes ropes and floats, biofouling and discarded shells. Methodology and calculations are further detailed in Appendix D. Figure 2 shows abandoned farms, inactive permitted farms that are likely to be abandoned in March 2015 when the permits expire, and also active farms.

The table below provides an estimation of type of debris, tonnage and volume. These estimations should be treated with caution and are likely to contain a significant margin of error. The calculations were undertaken based upon field inspections, weighing materials, knowledge of the areas and standard assumptions for typical layouts (ie. length of lines, spat collectors and chaplets, float spacing, % of lines with chaplets and spat collectors, fouling rates).

Type of Farm	Type of Debris	Estimated Disposal (metric ton)	Estimated Reuse / Recyclable Tonnage (metric ton)
Abandoned Farms	Ropes / Anchor rope / Chaplets / Spat collectors	34.2	0
	Floats	8.5	8.5
	Biofoul / Oysters (includes discarded live oysters)	193	88 Saleable Oyster Shell
Inactive Permitted Farms (Material required to be removed when permit lapses in March 2015)	Ropes / Anchor rope / Chaplets / Spat collectors	18	0
	Floats	4.6	4.6
	Biofoul / Oysters (includes discarded live oysters)	81	36 Saleable Oyster Shell
Active Permitted Farms (Material required to be removed to make compliant)	Ropes / Anchor rope / Chaplets / Spat collectors	6.5	0
	Floats	1.7	1.7
	Biofoul / Oysters (includes discarded live oysters)	29	13 Saleable Oyster Shell



LEGEND

- Areas Actively Farmed March 2015
- Areas Likely to be Abandoned in March 2015
- Abandonded 1997 and 2011 Farms
- Roads
- Vegetation
- Island Outline

Paper Size A1

0 0.2 0.4 0.6 0.8 1

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: WGS 1984
Grid: WGS 1984 UTM Zone 4S

N

GHD

Ministry of Marine Resources, Cook Islands
Manihiki Lagoon Black Pearl Strategic Environmental Assessment

Job Number 51-32979
Revision B
Date 14 May 2015

Pearl Farm Status

Figure 2

G:\51\32979\GIS\Maps\Mxd\5132979_G002_RevB_Figure 2_Pearl Farm Status.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: MMR: Farm areas - Feb 2015; GHD: Farm Status - Mar. 2015. Created by:jhchen

It should be noted that it is the responsibility of the farmer to have for permitted areas to make their farm compliance, and also remove the gear when the permit lapses (likely for currently inactive permitted farmers). Given the historic poor record of enforcement, it is anticipated that the currently permitted areas that are not actively farmed - will be also abandoned assuming that the permits are not renewed in March 2015.

The clean-up described in this report is largely focused on the unpermitted abandoned farming equipment, as per the original brief.

3.4 Definition of Significance Criteria

For the purposes of the environmental impact assessment, we have adopted Wood's[39] definition of significance:

Major Where the extent of the impact is large in scale or magnitude as a result of high sensitivity to change or a high intrinsic value and as a consequence the integrity or that asset will be significantly changed. The impact is of national or regional importance, and will be of long term nature (or very severe short term) irreversible and certain or likely to occur.
Moderate Where the extent of the impact is small in scale or magnitude as a result of low sensitivity to change or a low intrinsic value and as a consequence the integrity or that asset will be significantly changed. The impact is of district importance. The impact will be of medium or short term nature and likely to occur.
Negligible Where the extent of the impact is barely noticeable in scale or magnitude as a result of low sensitivity to change or a low intrinsic value and as a consequence the integrity or that asset will be significantly changed. The impact is of local importance. The impact will be of medium or short term nature and unlikely to occur

3.5 "Do Nothing" Scenario

A "do nothing" scenario is considered in order to assess what would happen if there was no change to the current situation. This section outlines the impacts of leaving the materials in place.

The potential impacts of leaving the derelict farming equipment in place include:

Positive

The positive aspects of leaving the derelict farming in place include:

- Underwater spat sorting platforms and other materials form a "fish attracting device" (FAD) and therefore support fish communities in otherwise barren parts of the lagoon;
- The derelict equipment provides a substrate for various sponges, bivalves, soft corals and anemones. These may include ecologically significant species, however given the lack of information and cataloguing of species in the lagoon, this cannot be confirmed;
- Some of the abandoned farm equipment is in good condition. With simple maintenance tasks could remain in the lagoon and be reused – that is reduced labour and capital inputs

[39] Wood, G. (2008). Thresholds and criteria for evaluating and communicating impact significance in environmental statements: 'See no evil, hear no evil, speak no evil'?. Environmental Impact Assessment Review, vol. 28:1. S. 22-38. ISSN 0195-9255.

to re-establish a pearl farm.   This approach is only recommended if there is a pearl farmer who wishes to take over the management of the area.

Negative

- Abandoned lines cause a navigation hazard for boats were lines / floats are at the water surface;
- Abandoned lines may cause an entanglement hazard to sea turtles, and other large sea creatures.
- Biofouling on discarded equipment contributes to the nitrogen loading in the lagoon, therefore impacting water quality through potential nutrient enrichment;
- Discarded live oysters are likely to be a significant contributor of nitrogen in the lagoon, therefore impacting water quality;
- Discarded equipment in some instances where floats are at the surface pose a navigation hazard;
- Discarded equipment may pose a entanglement hazard to larger aquatic wildlife;
- Discarded equipment entanglement with operating farms;
- Abandoned farms limit the area available for existing permitted areas to expand or for new farms to establish;
- It is poor environmental stewardship to leave the abandoned equipment in the lagoon.

On balance, the negative effects of leaving the derelict equipment in the lagoon outweigh the positive aspects. The impact of leaving the equipment in the lagoon is considered to be moderate, with potential major effects if nutrient enrichment continues. This is a particular concern in relation to the potential for eutrophication of the lagoon.

3.5.1 Microplastics

Recent research into microplastics has identified that these pollutants are persistent in the environment and bio-accumulate up the food chain[40].

Microplastics are also known to accumulate persistent organic pollutants (POPs), and therefore can also be toxic[41]. It is not expected that this would be an issue for Manihiki as there is limited sources of POPs.

The ongoing presence of discarded farming equipment such as nylon ropes and floats is likely to be acting a source of microplastic pollution within the lagoon, through long term weathering processes[42].

Corals are known to ingest microplastics[43], which could potentially impair coral health. As such, the removal of plastic farming detritus is likely to contribute to the long term recovery of the lagoon ecosystem.

Overall the generation of microplastics is anticipated to have low to moderate impact. It should be noted that the microplastics have not been assessed in detail as part of this project.

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[40] Browne, M.A., Galloway, T. and Thompson, R. (2007) Microplastic – an emerging contaminant of potential concern? *Integrated Environmental Assessmenmt and Management* 3(4): 559-561

[41] Andréfouët, S., Thomas, Y., & Lo, C. (2014). Amount and type of derelict gear from the declining black pearl oyster aquaculture in Ahe atoll lagoon, French Polynesia. Marine pollution bulletin, 83(1), 224-230.

[42] Ibid

[43] Hall, N.M, Berry, K.L.E., Rintoul, L and Hoogenboom, M.O. (2015) Microplastic ingestion by scleractinian corals*. Marine Biology* 162: 725-732

3.6 Water Quality Impact

3.6.1 Derelict Equipment Removal

Based upon the trial removal of the equipment, it was observed that during the removal process there was some minor loss of biofouling from the equipment and also some mobilisation of biogenous and lagoon floor sediment into the water column. These impacts are minor and not expected to impact water quality. Overall the impact of the removal of the equipment on water quality is likely to be positive and moderate, with anticipated observable improvements over time.

3.6.2 Disposal of Equipment and Organic Waste

It is anticipated that some of the equipment, such as floats, will be able to be reused or recycled. Based upon farmer's preferences, it is not likely that ropes will be reused and will require disposal along with the biofoul and oyster flesh. The oyster shells will generally be able to be sold on to the Asian garment marketing industry for button manufacturing. This is described further below.

The most practical way to dispose of unwanted ropes and organic waste materials is to dispose of these on land in a pit. The pit needs to be located on the ocean side of the island as any groundwater that may be impacted by the waste materials would likely discharge to the ocean side of the atoll. There are a number of limitations with this option that will need to be considered further including, land availability, acceptance by landowners, and on-going environmental impacts.

The rope that would be recovered is largely inert and not expected to have any ongoing impacts to the environment once discarded into a pit beyond acting as landfill. The organic material intended to be discarded may, as it breaks down, leach nutrients that could lead to contamination of groundwater and may alter (lower) the pH. This effect is considered to be moderate, however the overall impact on the receiving environment – the ocean reef - flat is likely to be negligible due to water mixing and dilution. Any burial pits should be located well away from households to minimise the risk of impacting water quality of groundwater wells.

3.6.3 Longer Term Water Quality Improvement

In the long term, it is anticipated that the removal of the derelict farming equipment and discarded live oysters will realise an improvement in water quality of the lagoon.

A study[44] undertaken at Port Stephens in Australia has shown that for every tonne of pearl oysters (*Pinctada imbricate)* harvested, 0.7 kg of metals, 7.45 kg of nitrogen and 0.545 kg of phosphorus are removed from the ecosystem at the time of harvest. The study also mentions that the mass of metals, nitrogen and phosphorous could be further enhanced by harvesting the oysters at a time of year when they are peak condition.

This study demonstrates that the removal of discarded shells would likely realise an improvement to water quality through removal of nutrients from the Manihiki lagoon ecosystem. Furthermore, these discarded shells may also have some residual value for the sale of "mother of pearl" for the arts and crafts, and button making industry.

Overall the impact on water quality is expected to be moderate to major and positive, with an overall net improvement in water quality over the longer term. This is also contingent on improved management practices and ensuring that sustainable pearl farming limits in the lagoon are maintained.

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[44] Gifforda, S., Dunstana, H., O'Connor, W., Macfarlanea G.R., (2005). Quantification of in situ nutrient and heavy metal remediation by a small pearl oyster (*Pinctada imbricata*) farm at Port Stephens, Australia Marine Pollution Bulletin, Volume 50, Issue 4, Pages 417–422

3.7 Noise Impact

Noise impact is likely to be negligible and no different than normal pearl farming operations such as operation of motor boats.

3.8 Ecological Impact

Based on anecdotal evidence, the ecology of Manihiki lagoon has been altered by over 30 years of pearl farming and associated nutrient enrichment of the lagoon. Removal of derelict farming equipment and discarded oysters will likely have a beneficial impact to lagoon ecology.

Removal of nutrients from the lagoon ecosystem, will have a longer term benefit. After several flushing cycles, lagoon nutrient levels are expected to reduce. This will improve the overall lagoon health, and over time (if low nutrient conditions are maintained) it is expected nutrient sensitive species (such as coral) to return to the lagoon over a longer term.

The biofouling communities present within Manihiki Lagoon are largely unrepresented across the wider natural lagoon environment. The ongoing presence of these communities is likely driven by their ability to foul discarded equipment, and as such is not considered to be the natural state of the lagoon. A short term loss in biodiversity is expected to occur with the removal of biofouling communities. However, if improvements in water quality are able to be achieved, it is expected that longer term recovery/recruitment of coral and benthic communities, representing the natural state of the lagoon, will occur. This may also see a shift in composition, with some organisms currently associated with the biofouling communities occurring within the reef complex.

Given the close linkages between coral reefs and reef fishes (e.g. Gilmour et al, 2013[45]), in the long term, as the lagoon returns to its natural state and greater coverage in biogenic benthic habitat is achieved, associated communities such as small fish and crustaceans are expected to increase in abundance. This has the potential to lead to an increase in presence of higher order predators such as pelagic fish and marine turtles.

3.9 Visual Impact

The abandoned farms have minimal visual impact, as generally they are under the water surface. Where anchor ropes have been snapped floats may be seen at the water surface.

The visual impact is only visible beneath the water surface. With the exception of pearl farmers, generally no other lagoon users venture below the water surface. As such visual impact is not an issue of concern.

Overall, the impact will be negligible and there will be a net improvement through the removal of the derelict equipment.

3.10 Amenity Impact

The primary amenity values of the lagoon include swimming, diving, snorkelling, collection of shellfish of arts and crafts, and fishing. The derelict farming equipment has minimal impact on these activities at present.

Any impacts on amenity would be minimal, with a net improvement if the materials are removed.

3.11 Social Impact

The community on Manihiki has understandably tight communities and families whom have existed here for many generations .As such the pearl farms seem to have stemmed from family

[45] Gilmour, J., Smith, L., Cook, K. and Pincock, S. (2013) Discovering Scott Reef: 20 years of exploration and research. Australian Institute of Marine Science. 179 pp.

run operations. As time has gone changes to Island culture and an increased knowledge of pearl farming impacts and economics has led to significant changes. The Island council is attempting to establish a more robust system in order to stabilize a previously 'boom - bust' activity.

A key component to a successful outcome of any clean-up operation will be the acceptance and support of the local community's. The feelings of ownership stem back through history, and while an pearl farm may be currently 'un-permitted' or be seemingly 'abandoned' there can still remain strong personal connections from family's that once farmed it. A robust process of discussion and education needs to be undertaken within all of the Manihiki community to ensure that a clean-up does not cause negative feelings, and that the community as a whole support it.

The Island Council have suggested that the best way to manage community expectations and perceptions around this particular issue is to hold a public meeting to discuss the issues at hand and that the equipment is required to be removed in order to improve lagoon health and for the net benefit of the wider community.

If appropriately managed, direct social impacts of the lagoon clean-up will be negligible. Longer term, through improved water quality and freeing up areas for farm expansion, there should be a net benefit.

3.12 Pearl Farming Impact

The removal of derelict farming equipment is not expected to have appreciable impacts on current pearl farming operations, based upon observations made during the removal trial described in Section 3.2. To minimise impacts a rigorous monitoring and management program will need to be implemented.

In the medium term, the nutrient balance will need to reach equilibrium after the removal of the discarded oysters and biofouled equipment. This may that phytoplankton flourish for a period after removal until balance is achieved in the nutrient dynamics of the lagoon. This may take a several lagoon flushing cycles to reach a balance.

This means that there may be an abundance of food available for the cultured oysters. There may also be a low risk of an algae bloom. The removal activities should coincide with summer, to reduce the algae bloom risk (commonly observed during winter periods).

The benefits to the pearl farming industry include:

- Freeing up previously occupied areas;
- Longer term improvement in water quality;
- Overall improvement in lagoon health; and
- Low cost re-useable floats (and potentially rope).

3.13 Economic Impact

A more detailed cost/benefit analysis is described in section 5.10 of this report. This provides a more generic overview of the economic impacts of the project.

The project will be split into two stages, firstly the recovery of the equipment and secondly the sorting, cleaning, and where necessary, the disposal of the derelict equipment.

The project will generate some short term employment for the local community through support diving, sorting, cleaning and disposal of derelict equipment.

The discarded oyster shells that are recovered could be cleaned, chipped and sold for arts and crafts, and button manufacturing. This would also generate some revenue for the community.

Longer term, the clean-up operation will allow existing farms to expand, and new ones to be established. This will need to be undertaken in a more controlled manner to ensure the long term sustainability and environmental stewardship of the lagoon.

3.14 Conclusion on Feasibility

Based upon this assessment, it is clear that there is a net benefit to undertaking the clean-up of abandoned pearl farms. With appropriate resources and support, this project can be completed largely by the local community, and this will also provide some short -term employment and training opportunities (such as diving skills).

4. Statutory Context of Lagoon Clean Up

4.1 Scope of Statutory Assessment

The intent of the statutory review is to determine that any proposed clean up methodology is compliant with local statutes, codes and plans.

The following statutes, codes and plans were reviewed as part of this assessment:

- Island Government Act 2012-2013
- Environment Act 2003
- Marine Resources Act 2005
- Manihiki (Natural Resources) By-Laws 2003
- The Manihiki Pearl Farming Management Plan 2006-2016
- Code of Practice for Responsible Pearl Farming in Manihiki Lagoon, 2006-2016

4.2 Island Government Act 2012-2013

4.2.1 General Overview

The Island Government Act sets out the structure, functions and powers of the individual local government authorities for the Cook Islands. The Act was enacted at the beginning of 2013 to allow the outer island governments to have more contribution to deciding the administrative, socio-economic, cultural, and environmental and development priorities of their islands. The Act sets out the process and parameters within which each government operates, including a code of conduct, their financial accountability, the ability to create bylaws, and the conduct of legal proceedings.

4.2.2 Applicability

This piece of legislation sets out the governmental context for the operation of the Island Council on Manihiki, within which this project would operate. There are no specific regulations relevant to the decommissioning of the farming equipment in the lagoon.

Ultimately, the clean-up operations will need to endorsed and approved by the Manihiki Island Council.

4.3 Environment Act 2003

4.3.1 General Overview

The Environment Act was enacted by the Parliament of the Cook Islands in November 2003. It applies to the islands of Rarotonga, Atiu and Aitutaki, and does not generally apply to any outer islands unless specified by the Queen's Representative by Order in Executive Council (as provided for in section 4(2). It is understood that in 2012 the Environmental Act extended to Manihiki.

4.3.2 Applicability

This Act is applicable to Manihiki, but as yet specific policy has not been developed for the island. It is understood that a steering committee will be established to administer the act on the island, and that this will comprise members of the National Environmental Service, Ministry of Health, Island Councillors, and community groups / NGOs.

4.4 Marine Resources Act 2005

4.4.1 General Overview

The purpose of the Marine Resources Act is to ensure the sustainable use of living and non-living marine resources for the benefit of the people of the Cook Islands. The Act focuses on fisheries conservation, management and development and it is administered by the Ministry of Marine Resources. It has specific controls on fishing (including pearl farming), as well as the penalties for infringing the controls.

4.4.2 Applicability

There are specific sections of the Act relevant to the project in terms of permissions, and how to carry out the decommissioning of abandoned pearl farms. The removal of fishing/aquculture devices belonging to another person or installed by the Government or a Local Authority is prohibited under section 27 of the Act. Before undertaking any decommissioning of pearl farming equipment from the Manihiki Lagoon, permission will be required from the person/entity who installed the equipment, as the removal will need to be authorised by them.

Section 19 states that no foreign vessel that may be used for fishing, or a related activity, shall enter the fishery waters (of which the Manihiki lagoon is included) except for a purpose recognised under International law or in accordance with a valid licence issued pursuant to the Act. Therefore, a licence may be required if foreign vessels are to be used for decommissioning. Section 36 sets out the process for authorisation made by the Minister of Marine Resources for scientific research operations. This may be relevant if research is required to understand the state of the equipment before it is removed from the lagoon. The Minister must authorise scientific research.

4.5 Manihiki (Natural Resources) By-Laws 2003

4.5.1 General Overview

The Manihiki Natural Resources By-laws apply to the island of Manihiki, to its lagoon, reef and surrounding waters. The By-Laws are split into seven parts; free diving, pearl farming, technicians, natural resource management, quality control and industry standards, enforcement, and penalties. They contain the law on the use of the lagoon, and specifically in terms of the gathering of oysters, and the practice of seeding in order to ensure a sustainable source of the shellfish. The By-Laws also delegated the right to put a restriction on particular areas to stop all taking of fish and other sea creatures to the Council of Manihiki. Section 17 delegates the right to prepare a draft management plan for the protection, conservation, management and control of the Manihiki lagoon to the Council. The Manihiki Pearl Farming Management Plan 2006-2016 (below) was created under this jurisdiction.

4.5.2 Applicability

This set of By-Laws is not applicable to this project, as the controls focus on specific activities to achieve sustainable farming of oysters and pearls. There are no specific regulations that apply to the removal of equipment from of the lagoon, or decommissioning of existing pearl farms.

4.6 The Manihiki Pearl Farming Management Plan: 2006-2016

4.6.1 General Overview

This document was created by the Cook Islands Ministry of Marine Resources for, and in consultation with, the Island Council of Manihiki following a bacterial pearl shell disease (Vibrio outbreak in 2000) which caused major production issues for pearl farming in the Manihiki

Lagoon. The Management Plan addresses the promotion, establishment and enforcement of environmentally sustainable pearl farming practices for the Manihiki Lagoon/fishery. It is a resource for farmers and industry stakeholders to guide their practices. The *Code of Practice for Responsible Pearl Farming in the Manihiki Lagoon* (below) is a supporting document. Both documents were created to inform conditions on the Pearl Farming Permits issued to Pearl Farmers.

The objectives of the Management Plan are

i. *Employ environmentally sound practices for pearl farming for the long-term future sustainability of the lagoon, both for those who live on the island of Manihiki and for future generations,*

ii. *Maintain the traditional values and practices of Manihiki society in harmony with the pearl farming industry,*

iii. *Enhance economic prosperity and encourage the full participation of all sectors of the Manihiki community in pearl farming for socio-economic development,*

iv. *Establish a transparent and accountable system of lagoon management for pearl farming in Manihiki lagoon,*

v. *Generate the best available information to assist with decision making on the management of the lagoon and pearl farming.*

4.6.2 Applicability

The Management Plan applies to decommissioning activities, as the removal of the farming infrastructure from the lagoon is an associated activity, managed in conjunction with all black-lip pearl oyster farming in the Manihiki Lagoon. Whilst the Management Plan mainly focuses on technicalities of Pearl Farming in the Manihiki Lagoon, and the permits required for this, of relevance to decommissioning is ensuring that the way in which the equipment is removed is in keeping with the permits of the different farms throughout the lagoon. The boundaries of each farm will need to be established to determine which permits are relevant.

4.7 Code of Practice for Responsible Pearl Farming in Manihiki Lagoon, 2006-2016

4.7.1 General Overview

The Code of Practice sets out technical regulations for pearl farming in the Manihiki Lagoon, to be administered by the Manihiki Island Council. The Code of Practice includes controls on the use of infrastructure for the farming, the use of chemicals in and around the Lagoon, and management of land-based activities that may also affect the health of the lagoon. This includes disposal of biofoul material, cleaning waste and rubbish.

4.7.2 Applicability

The Code of Practice is highly applicable to decommissioning of the equipment from the Manihiki Lagoon. In undertaking the work, specific controls concerning how to undertake activity in the Lagoon must be adhered to, including the conditions of each farming permit and more specifically, controls on the use SCUBA in the Manihiki Lagoon, chemicals and fuel (s 2.1.13 and 2.1.12). It is recommended that four stroke engines are used rather than two stroke, due to the large amounts of oil and benzene that are lost into the ocean from two stroke engines. In addition, the Code of Practice rules could be used as an indicator of historic activities in the Lagoon over the past nine years. For example, as the Code contains rules around the use of chemicals, fuel, pesticides and detergents in the Lagoon, and the use of imported farming materials, this may help in determining whether the infrastructure to be removed from the lagoon is contaminated.

4.8 Summary Table

Document	Overview	Applicability
Island Government Act 2012-2013	Sets out the structure, functions and powers of the governments for islands of the Cook Islands.	Sets the governmental context of Manihiki within which the black pearl farming and associated activities operate within. There are no specifically relevant regulations to the project.
Environment Act 2003	Provides for the establishment, powers and functions of Island Environment Authorities and the National Environment Services. The purpose is to protect, conserve and manage the environment in a sustainable way.	Not applicable. Recently extended to Manihiki but no specific policy developed for Manihiki.
Marine Resources Act 2005	Provides for fisheries conservation, management and development for the sustainable use of marine resources.	Requires permission to remove equipment from the person/entity who/that installed it (s 27). Requires authorisation from the Minister of Marine Resources for scientific research, if required (s 36).
Manihiki Natural Resources By-Laws	Contains the law for the use of the lagoon, specifically in terms of the gathering of oysters, and the practice of seeding, in order to ensure a sustainable source of the shellfish.	Not applicable, as focused on sustainable farming of pearls. There are no specific controls on the decommissioning/removal of equipment from the lagoon.
The Manihiki Pearl Farming Management Plan 2006-2016	The purpose of this Plan is to promote, establish and enforce environmentally sustainable pearl farming practices for the Manihiki Lagoon/fishery. It is a resource for farmers and industry stakeholders to guide their practices, and is therefore a technical document.	This Plan sets the requirement for farming permits in Manihiki, and conditions on these. The method for the decommissioning of the infrastructure should be in accordance with the conditions of the individual permits for each farm within the Lagoon.

Code of Practice for Responsible Pearl Farming in Manihiki Lagoon, 2006-2016	Technical document which sets the standards for pearl farming in the Manihiki Lagoon, to inform farming permits conditions.	Includes specific controls that must be adhered to during decommissioning of any equipment. May be used as indicator of the state of the equipment in the lagoon in terms of contamination,.

5. Lagoon Clean Up Methodology

5.1 Description of Removal Options

When considering options it is important to consider the remoteness of the islands, available local equipment, and local skills and experience.

This following section describes options that we believe will be viable given the limitations described above. In particular, the assessment focuses on the removal of derelict pearl farming equipment as described in the original request for tender (ID# 141508).

5.2 Consultation

Prior to commencing any clean-up operations, consultation should be undertaken with the following primary stakeholders:

- Manihiki Island Council
- Ministry of Marine Resources
- Manihiki Pearl Farmers Association
- Local Community Meeting.

The removal of historic derelict equipment is likely to be a contentious issue with the local community and pearl farmers, and therefore communication is key to execution of a successful project.

Some of the areas may be suitable for re-establishment. Pearl farmers should be consulted to see if there are some areas that they wish to take over, if so the project team should work with the farmers to see if re-establishment will work. It should be noted however, that farmer preference is generally to remove old equipment, and install new ropes and floats (used floats may be used).

5.3 General Proposed Approach

There are a few options for the removal and disposal of the derelict equipment in the lagoon, however the most practical solution is to maximise the use of resources and labour available on Manihiki. This approach will mean that some of the project expenditure is reinvested into the local community.

Given that the environmental impacts of the remedial work and the potential impacts on the pearl farming operations are thought to be minim, it makes sense to undertake the project over a relatively short timeframe.

Furthermore, MFAT has indicated that there is a capped budget for the clean-up project, and as such, the clean-project is only feasible if undertaken over a short timeframe, assuming that it will not be undertaken on a voluntary basis by farmers.

Time frames are further described in section 5.6 below.

The proposed approach includes:

- Use of a commercial dive team (4 commercial divers) to supervise and manage the dive programme and Manihikian diver safety;
- Utilisation of local divers (4 Manihikian Divers) to assist with the recovery work;

- Divers to cut anchor lines to lift equipment to water surface, using attached floats or lift bags where necessary;
- Where the lines are sunken with no floats attached, lift drums or bags will be used to lift the equipment to the surface.

5.3.1 Consideration of Alternatives

Whilst there are some alternatives to the above approach, for the reasons described below we believe the above approach is most appropriate.

Incentivised Community Approach

A community based approach would appear to be a viable alternative. The approach could use a pro-rata rate (e.g. per kg of rope recovered, number of floats recovered, or flat rate per farm) for farm equipment removal.

For derelict farm equipment removal, we believe this approach would not be effective for the following reasons:

- Lack of motivation and drive in the local community;
- Potential negative/conflict perception of divers in the local community (i.e. families may not want equipment removed);
- Conflict with other work commitments;
- Limited number of qualified divers therefore potential conflict with pearl farming demands;
- Increased safety risk if undertaken on intensive programme (i.e. consecutive diving days);
- Shortcuts may be undertaken in derelict equipment removal;
- Programme likely to be drawn out.

We consider that the incentivised community approach would work best for the land based activities of sorting, cleaning and disposal.

Mechanised Removal

An industrial scale operation using a barge and rope recovery equipment would allow a high level of productivity and number of derelict farms could be removed in a day. However, it does not remove the need for divers to sever the anchor lines. The use of such equipment would also come at significantly higher costs, and also presents logistical issues with getting the barge over the reef flats.

5.4 Removal of Derelict Equipment

A summary of the proposed diving and derelict farm recovery methodologies are provided in Appendix C. This section of the report provides a brief overview and rationale.

5.4.1 Commercial Diving Crew

It is recommended that a commercial diving crew be engaged to manage the removal of the derelict pearl farming equipment. The advantages of using a commercial dive crew include:

- ***Safety Management:*** This is the main reason for engaging a commercial dive team is to minimise the safety risks. Commercial divers are familiar with extended field diving programmes and as such understand how to manage the risks. The commercial dive team would work with local divers to ensure that the programme is completed in a cost and time effective manner.
- Certainty of outputs and performance can be managed through contractual mechanisms;

- Certified to diver depths greater than the ticketed divers on Manihiki;
- Experience with marine salvage programmes;

5.4.2 Local Divers

Certified local divers would support the commercial dive crew to ensure that the work is completed in a cost and time effective manner.

5.4.3 Local Resources

The recovery of the equipment can be largely completed using locally available resources including:

- Large council owned pontoon boats;
- Diver gear;
- Dive cylinders and compressor for refills;
- Excavator / Tractor for offloading bulk bags
- Labour
- 1m^3 bulk bags (inventory check recommended)

5.5 Estimated Weights / Volume of Material to be Disposed

Table 4 provides a rough estimate of the tonnage and volume of material requiring disposal from abandoned farms. These estimates will have a margin of area as detailed surveys and measurements of all the derelict sites could not be undertaken in the time and budget constraints for this project. The numbers have been calculated using standard assumptions, measurements of weight of material and inspections of most of the derelict farming areas.

The summary table shows that a percentage of the materials have some residual value in terms of reuse or as a saleable product. These are described further tin the relevant sections below.

Type	Estimated Total Number	Estimated Total (Metric Tonnes)	Estimated Disposal Weight (Tonnes)	Estimated Recycle / Reuse / Saleable Number	Estimated Recycle / Reuse Weight (Tonnes)
Floats	4,243	8.5	0	4,243	8.5
Rope	-	34	34	0	0
Biofoul	-	16.5	16.5	0	0
Oysters	450,857	176	88	225,428	88
Totals	-	235	138.5	-	96.5

Table 5: Summary of materials requiring disposal

5.6 Disposal of Derelict Equipment

The other important aspect to consider for the clean-up project is the disposal of the waste materials. Some of the material, such as the floats are likely to be suitable for reuse and may have some residual value. This is discussed further below.

5.6.1 Predicament Posed by Chinese Funded Pearl Farming Equipment

It is understood from MMR that ten 40ft (12.2 m) containers of ropes, floats, spat collectors, vomit bags and chaplets have been by donated China Aid (Chinese Government). This equipment will be delivered to Manihiki in March 2015.

The donation of this equipment poses a number of issues for the lagoon clean up:

- Makes the reuse of the old floats and other equipment less desirable;
- Should all the equipment be utilised to establish new farms, it is very likely that the sustainable pearl farming limits will be well exceeded;
- May lead to future abandonment of equipment if controls are not improved with a bond imposed.

5.6.2 Cleaning

The derelict equipment will be received to shore in $1m^3$ bulk bags. Where possible the equipment will be sorted into floats and ropes on the boat.

Peal farmer preferences have indicated that there is little desire to reuse old ropes, given that new rope can be purchased at minimal cost due to subsidies. This means that there is little point in cleaning discarded ropes.

The cleaning of the materials is largely related to the removal of the biofoul. This is not considered necessary for the ropes as these can be disposed with the biofouling attached, especially if disposed of in burial pits on Manihiki. In the event that disposal is required further afield, then it may be prudent to remove the biofouling for hygiene / biosecurity reasons.

The cleaning of the equipment will require the manual removal / chipping of the bio-fouling using hand tools and local labour. A “per item” cleaning rate could be established for floats to drive efficiency with the use of local labour.

5.6.3 Floats

The types of floats are varied but generally comprise spherical plastic floats with one eyelet. Many if of the floats were supplied by Quality Equipment in New Zealand. These floats are made of Acrylonitrile butadiene styrene (ABS). Other types of floats include 25 and 60 L High Density Polyethylene (HDPE) plastic drums (Examples of floats provided in Appendix A).

Reuse

Many of the floats that are recovered from the lagoon are likely to be suitable for reuse, however sun exposed floats (such as those at the surface) may become brittle and may not be suitable for reuse.

Given the pending arrival of new Chinese funded floats (discussed further in section 5.6.1), the reuse of old floats may become a less feasible prospect. Currently pearl farmers purchase the equipment at 20% of the supplied price. The current cost is NZD$2.4 per new float (assuming a wholesale landed cost of the float is NZD$12). The used floats could be sold at a nominal rate of NZD$1 per float to assist with some of the cost recovery, however given the low incremental costs, the new floats are likely to be more desirable.

Novel Reuse of Floats

There are number of potential novel reuses of the floats including:

- Half floats could be used to augment the Manihiki hydroponics system;
- Half floats could be concrete filled and used as anchors for deeper areas;
- Rafted together to create Fish Attracting Device (FAD) for ocean fishing;

- Chipped plastic may be able to used as alterative to gravel in drainage or similar application, providing the engineering requirements are met;
- On sold to Rakahanga or Penhryn for their own attempts at aquaculture.

Whilst novel reuse may account for some of the surplus floats, it is unlikely to have a significant impact on the number of floats requiring disposal.

Float Recycling

Should the recovered floats not be reused, this would mean a surplus of 4,200 floats on Manihiki. In light of the new Chinese funded floats, it may be prudent to consider recycling or disposing the floats rather than reusing them.

ABS is a readily recyclable plastic. One of the nearest recycling facility is Astron Plastics, located in East Tamaki, Auckland, New Zealand. The most cost effective to reducing volume and shipping costs would be to cut the floats into quarters using a band saw, and stack into 1 m^3 bulk bags for shipment. This could be containerised upon ship loading.

An issue with potentially using a band saw is the high volume of floats requiring disposal. This increases the likelihood of injury for people using the band saw. This risk may be able to be minimised through appropriate training and use of Personal Protective Equipment (PPE) – however a residual inherent risk will remain.

An alternative to manual processing could be to use a chipping plant. This is a higher cost alternative, with lower safety risk as the floats would be simply fed into a hopper. The spherical form of the floats may make them difficult to process using a rotary cutting blades, and therefore a trial is recommended prior to committing to this option. Advantage of this option is that float processing time and cost is likely to be reduced, and the volumes will also significantly reduce, and thereby reducing shipping cost. A disadvantage is that the plant will require 3 phase power, and as such may need to be located next to the generator to minimise installation cost. Given the remoteness of Manihiki, renting a suitable machine is not considered viable.

The purchase price for a chipping machine large (specification of a suitable plant is provided in appendix B and powerful enough to process the floats would be in the order of $55-60K (+VAT +delivery). The costs of shipping are also likely to be significant as the suitable plant is in the order of 1,500 kg.

This high price may not make this option viable given the relatively short project time frame (<3 months).

Astron has indicated that they would pay in the order of $0.12 per kg, meaning that a nominal NZD$1,020 could be recovered from this recycling activity. The cost of shipping is not likely to make this a viable prospect, nor would it be a sustainable option given the fuel that would need to be expensed to ship to Auckland.

Float Sorting

If floats are to be recycled, they will need to be sorted by type and colour to ensure that the packaging requirements of the plastic recyclers are met. This will not be required in the event that disposal or novel reuse route is chosen.

Float Disposal

Disposal of the floats on Manihiki is not desirable as there are no municipal landfills and as such waste disposal is largely uncontrolled. The burning of refuse is a common practice on the island. Whilst the ABS plastic has a high calorific value and will burn well, at low temperature combustion temperatures, toxic (dioxins, furans, polycyclic aromatic hydrocarbons) compounds are created. Whilst given the island environment, the release of these chemicals into the air are not of great concern as they will dissipate and disperse quickly in the trade winds, and settle into the ocean with rain events.

The main concern with these chemicals is that they can adhere to the soil – and thereby impacting potential future use of the soil in vicinity of the burning areas. The health of free ranging pigs that graze in this area may also be impacted if this approach is taken, and as such open pit burning is not recommended.

Whilst there are some high tech solutions available for conversion of plastics (such as pyrolysis, and thermal depolymerisation) into fuels, these are often costly and energy intensive, and therefore not considered appropriate for this project.

One option that has been explored is chipping the floats and using it as complimentary feedstock for the Rarotonga Hospital incinerator. This is a high temperature incinerator (700℃) and therefore toxic chemicals will be destroyed.

Aitutaki has the nearest controlled waste disposal facility. Whilst it does not comprise a engineered landfill, it is managed in a controlled fashion. It is operated by Aitutaki Council. Initial discussions with the council have indicated that they may be willing to accept the waste material upon confirmation of the type and volume of material requiring disposal. Disposal at Aitutaki is considered one of the preferred options for disposal.

5.6.4 Ropes

The ropes are generally made of polypropylene that has high durability and longevity. Pearl farmers have indicated that there would be little desire to reuse old ropes, due to a perceived weakening of the rope over time and the risk that rope breakage may pose to their crop. Given the low cost of the subsidised new rope, the preference is to use new materials.

This means that most of the rope that will be recovered as derelict equipment will require disposal.

Polyproplyene is a difficult to recycle and there are only a limited number of companies that offer this service in Taiwan and China. Recycling of rope is not considered viable due to transport costs, and also due to the presence of biofouling / dirt on the rope.

Given that most of the rope will have biofouling adhered to it, local disposal is considered appropriate. A purpose built disposal pit should be constructed on the ocean side of the atoll away from residential properties in order to minimise the risk of nutrients associated with the biofoul decay re-entering the lagoon or impacting bore water. Once the project is complete, the pit should be back filled.

Given that the village council owns no land, disposal will need to be undertaken on privately owned land. Agreement will be sought with a land owner before proceeding down this disposal route.

There may be some novel uses for the ropes also, such as weaving for mats or baskets, however this is not likely to have a significant impact in reducing the vast volume of rope requiring disposal.

5.6.5 Biofoul

The biofoul associated with the ropes will not be removed and disposed with the rope as described above. Any additional biofouling that will need to be removed relates to floats and float drums.

Biofoul will need be manually removed using hand tools. The biofoul should be disposed at the same location as the ropes.

5.6.6 Shells

The discarded shells that will be recovered as the part of any clean-up operation will need to be cleaned of organic material and biofoul removed - the shells have value. Currently one of the pearl farmers exports one container of cleaned and graded shells to Vietnam, where the shell is used to manufacture garment buttons. The buyers pay approximately $3000 per tonne of clean shell.

Based upon our estimates, the discarded shells from the abandoned farms have a potential value worth in the order of $264,000. This money could be used to offset project costs, or redirected back into a fund to support the pearl industry.

It should be noted that the sale of discarded shell would need to be undertaken in a controlled manner; otherwise the price might be adversely affected.

5.7 Institutional Strengthening

5.7.1 Capacity Building of Manihiki Island Council

It is clear that one of the major issues (reason for non-compliance and farm abandonment) is lack of enforcement by Council. This lack of enforcement appears to be largely due to life in a small community and the unwillingness of council members to punish neighbours, friends or family.

Council understands their role and what they are required to do, but the social constraints make this difficult.

Council would benefit from training relating to enforcement and will benefit from gaining an appreciation of the full cost of the farming operation as described in this report.

Bonding Pearl Farmers

A practical solution to this social constraint is to "bond" farmers at the time of permit renewal or at the time of new application. The way this would work is that the pearl famers would be required to pay a bond too council. Council hold the bond until the farming equipment is removed at the end of the permit or life of the farm. Farmers will only receive the bond back if the farm is removed and tidied up.

The value of the bond needs to be significant enough to motivate clean up by the farmer. After a minimum bond is set, the larger farms could also be prorated to accommodate for the scale of any potential clean up.

This approach would reduce the enforcement costs to council. This approach is commonly used in the mining industry to allow for environmental clean-up in the event of mine closure. An alternative to bonding used by the mining industry, that a percentage of earnings gets paid into a clean-up fund. This secondary approach is unlikely to work in this instance given the current low revenues from pearl farms.

Banning Discarding Oysters in the Lagoon

The Lagoon Management Plan, Code of Practice, and Permit system need to amended to ban the discarding or "storing" of oysters in the lagoon. As noted in this report, these discarded oysters are likely to have a significant contribution to nutrient loading in the lagoon, contributing to the the decline in water quality.

Community Awareness on Lagoon Ownership

Should the lagoon clean-up programme proceed, Council need to hold a public meeting with the community to discuss the planned works and also clarify lagoon ownership, and refute perceived family rights to historically farmed areas.

Setting Maximum Pearl Shell Limits

There does not appear to be a maximum limit set for how many shells are permitted to be farmed in the lagoon – meaning that there appears to be no mechanism to stop issuing permits to beyond the sustainable limits of the lagoon. Whilst the current recorded stocking rate appears to be below lagoon carrying capacity, there is a risk with the availability of new materials and equipment that stocking rates may increase over sustainable levels.

Whilst in the current market with low pearl prices, is not likely to a significant risk, however if the price increases this may change.

5.8 Timing and Time frame

It is anticipated that the removal of equipment can be undertaken over a 6 week period. Land based cleaning, sorting and disposal may take up to 2 months.

The removal works should coincide with a period that is not busy for pearl famers, and also not during winter months as this may coincide with increased nutrients and risk of algae blooms.

5.9 Rough Order Cost of Clean Up

5.9.1 Cost Assumptions

The following cost summary was based upon the following assumptions:

- Are based upon the material estimates determined for the derelict equipment during this project;
- Only relates to the 1997 and 2011 abandoned farm concessions;
- Assumes project to be managed independently
- Assumes that 8 crew dive team can complete the removal of the equipment in 36 working days;
- Travel costs for commercial dive crew mobilising from New Zealand

Risk and Uncertainties

The costings also have inherent risk and uncertainties including:

- Inclement weather increasing working times
- Uncertainties in material estimates
- Processing time estimates
- Productivity rates for on shore processing.

5.9.2 Cost Summary

The following table provides rough order costs of the clean up as described throughout this section of the report. This cost estimate only relates to the costs for the removal of the derelict farming equipment.

Item	Rough Order Costs (NZD$ excl GST)
Project Management	$30,000
Remediation Implementation Plan	$8,000
Flights For Commercial Dive Crew	$18,000
Accommodation and Meals (4 Persons - 56 days)	$25,000
Commercial Diver Crew, and Equipment (4 Persons 48 days)	$125,000
MMR / NES Divers Labour Costs (Zero rated) (2 Persons)	$0
Local Divers (2 Persons)	$24,000
Fuel	$5,500
Rental of Council Poontoon Boats (Zero rated)	$0
Materials (Bulk bags, binding tape)	$4,000
Local Labour for cleaning, sorting, packing (6 Persons, 12 weeks)	$28,800
Shell Cleaning for Export (Zero Rated – cost neutral)	$0
Local Disposal Costs	$6,000
Aitutaki Disposal Costs	$1,500
Waste Shipping to Aituitaki (assuming 100 $1m^3$ bulk bags)	$33,400
Waste Handing at Aitutaki	$4,000
Council capacity building	$26,000
Monitoring programme improvement	$12,000
Band saw	$2,500
Miscellaneous (tools, safety equipment, shipping)	$12,000
Contingency 15%	$62,858
Total	**$428,558.00**

It should be noted that the cost might be able to be offset by the sale of discarded oyster shells which has a potential saleable value of **$264,000.**

5.10 Benefit/Cost Analysis

This benefit/cost analysis (BCA) has been prepared based on information provided by MMR and information collected by GHD during the site visit in February 2015. The estimates of values for the benefits provided are based on desktop sources supplemented by stakeholder consultation with Ministry of Marine Resources, Cook Islands Pearl Authority, Manihiki Pearl Farmers

Association, Department of Statistics and Ministry of Finance and Management - Development Division.

The aim of the BCA is to assess the economic efficiency of removing discarded farming equipment from the lagoon and associated impacts on the profitability of pearl farming. That is, do the benefits outweigh the costs to society. A fundamental goal of BCA is to incorporate, as far as possible, impacts that are not traded in open markets, in this case the associated environmental benefits arising from the removal of derelict farming equipment within the lagoon with the overall goal to revitalise the Manihiki Pearl industry, create jobs and improve community wellbeing.

5.10.1 The base case and project scenario

Standard practice in cost-benefit analysis (CBA) is to establish and clearly enunciate the 'with' and 'without' (do nothing) project scenarios. The 'without' project scenario (or base case) is fundamental to the cost-benefit analysis and defines the situation in the absence of the project.

Under the base case, it is expected that pearl farming remains at current production levels while water quality remains impacted as a result of nutrients being released from discarded shells on the bottom of the lagoon. The ecological condition of the lagoon will also continue to be degraded.

Under the 'with' project scenario, it is expected that in the short term the removal of derelict farming equipment is not expected to have any appreciable impacts on current pearl farming operations. In the longer term, the clean up operation will allow existing farmers to expand and new ones to be established providing a long term benefit to the Cook Islands Pearl Industry.

5.10.2 Benefits

Pearl Production

It is estimated that pearl farming operations cover approximately 10% of the 4,4 ha of the lagoon. As derelict equipment is removed, it is expected that new areas within close proximity will gradually be opened up for pearl farming. Anecdotal evidence suggests that over time output from the lagoon could double from a current base level of 480,000 hanging oysters (see section 2.4.2). As new areas are developed, GHD has however taken a conservative estimate of annual production from a further 150,000 hanging oysters with an average net income per hanging shell of $2.90[46]. indexed to 2014 NZD

Water Quality

Increased quality of pearls from Manihiki Lagoon in the long term will be directly related to an improvement in water quality (see Section 3.6). The economic analysis has factored in a 5% premium in the price of black pearl. Anecdotal evidence suggests that the best quality pearls were harvested from the lagoon in the 1980s. The increase in pearl quality has been modelled as a 5% increase on the net return on pearl production which will occur approximately 10 years after the derelict farming equipment has been removed.

Improvements in ecological condition of the lagoon

In the long term as derelict farming equipment and discarded shells are removed from the lagoon it is likely to lead to an improvement in the ecological condition of the lagoon as nutrients are removed from the Manihiki lagoon ecosystem. A number of studies have valued the amenity value of coral reef ecosystems. NOAA (2013)[47] valued the total economic value of United States

[46] The Agribusiness Group, (2010) Pearl Farming Profitability Review – Part 2
[47] NOAA Coral Reef Conservation Program. 2013. The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. Silver Spring, MD: NOAA

coral reefs. This study examined a number of States and Territories; however this analysis adopted the economic value for American Samoa reflecting geographic proximity to Manihiki. Our analysis adopted a figure of $37.34 per hectare (indexed to 2014 NZD) for this study to reflect the amenity value of the lagoon. Any discernible improvement in water quality is not expected to be realised until sometime into the future and will only remain until the condition is returned to a pre-existing level.

Salvage value of discarded items

As discussed in Section 5.6.3, the plastic floats will be able to be resold at $1 per float and the analysis assumes that 50% of these floats will be able to be recycled. The analysis also has factored in the sale of 88 tonnes of discarded shells for $3,000 per tonne.

5.10.3 Costs and timeframes

The costs and timeframe and rough order of costs to clean up the lagoon are outlined in section 5.8 and 5.9.

5.10.4 Benefit-Cost Analysis

BCA is a technique commonly used to appraise public investments to determine whether they represent an efficient use of resources from society's point of view. The time frame for this analysis is 25 years and uses a discount rate of 7.5% to convert the streams of benefits and costs to present day values.

The results report the present value of net benefits in terms of the Net Present Value (NPV). In general, if the present value of the net benefits is positive it will be economic for society to allocate resources to the project.

A second measure of the BCA outcomes is the benefit-cost ratio (BCR). The benefit cost ratio is the present value of the benefits divided by the present value of the cost. A BCR greater than one means that the economic benefits exceed costs for the project.

Immediate removal of derelict farming equipment from the lagoon will result in a BCR of 9.98 and a present value of $3,849,666 as outlined below in Table 6.

Scenario	Benefits	Costs	NPV	BCR
Lagoon clean up	$4,278,223	$428,558	$3,849,666	9.98

Table 6 Results of benefit/cost analysis

6. Conclusions and Recommendations

6.1 Conclusions

This assessment has shown that there would be a net benefit in the removal of the derelict black pearl farming equipment from Manihiki Lagoon. In particular, the removal of biofoulant and discarded live oysters (including those on chaplets and spat collectors) will reduce nutrient enrichment with in the lagoon, and overtime improvements should be observed in lagoon water quality.

The recommended clean-up methodology includes:

- Engagement of a professional dive team assist with the salvage
- The professional dive team will be supported by a local dive team
- The derelict gear and discarded oysters will be removed manually using the council pontoon boats
- On shore sorting, cleaning and processing will be undertaken by the local community
- Ropes could be disposed of locally in a formed pit on the ocean side of the atoll
- Floats would be suitable for reuse, however with new aid funded floats arriving on the island reuse may not be an attractive option.
- Floats may be suitable for recycling however, value of the scrap plastic is minimal and the shipping costs will probably not make this viable.
- It is recommended that the float plastic is disposed of off Manihiki, given the limited capacity for waste disposal on the island. Aitutaki landfill is considered a suitable disposal location.
- Costs are likely to be in the order of $360-430K for the clean-up of derelict farming equipment.

6.2 Recommendations

Recommendations for Clean-up

- Seek legal opinion on section 27 of the marine resources act. Seeking permission from the people that installed the pearl farming equipment would impede progress of any lagoon clean-up operations.
- Consultation with the community and pearl farmers is required to get “buy in” and the need for holistic change
- Combination of commercial dive team and local dive team for salvage operations
- Local onshore team for sorting wastes
- Combination of disposal on Manihiki and disposal on Aitutaki
- Development of a Remedial Action Plan for the implementation, including staging to minimise risks of the clean up to continuing pearl farm operations
- Development of a “clean up” monitoring programme to set base line conditions prior to during, and after the clean up in order to manage environmental risks.

Recommendations for Pearl Farming Practices

- Ban discarding or “banking” surplus oysters in the lagoon

- Ban the removal of biofouling of active farm equipment within the lagoon. Biofouling should be disposed on land on the ocean side of the atoll
- Monitor more closely the disposal of terminated oyster shells in the lagoon.
- Bond farmers to ensure removal of equipment
- Community awareness on lagoon ownership
- Setting and monitoring maximum farmed shell limits

Recommendations for land based activities

- Bund installation around generator diesel supply tanks. Secondary containment at other fuel storage locations around the island
- Ban pig farming in areas close to the lagoon shore
- Consider relocation of septic tank fields to ocean side of the atoll. Practically this may be difficult to implement given most of the residences are located on the lagoon side of the atoll. Community discharge fields may be an option worth considering

Recommendations for Further Environmental Studies

The water chemistry and vertical mixing is not understood and needs to be investigated so that potential risks (through algae blooms or further nutrient enrichment) can be better understood. This should include:

- Depth profiling (nutrients and physio-chemical parameters) to the lagoon floor including the deepest parts of the lagoon. This needs to be undertaken over an extending period and seasonal variations;
- Nutrient content of sediment pore water in the deeper areas should be studied to better understand nutrient flux in the lagoon.
- Lagoon flushing needs to be better understood as it may affect the sustainable limits of the lagoon.

Monitoring Programme Improvement and Capacity Building

The monitoring programme needs to be improved to include depth profiling of the water column (nitrate / nitrite, ammoniacal-amongst other nutrients are likely to be most concentrated near the sea floor).

Appendices

Appendix A – Photo Log

Photo 1: Example of spat collectors in the foreground and chaplet lines in the background - abandoned farm	
Photo 2: Heavily laden spat collectors on abandoned farm	
Photo 3: Chaplets on abandoned farm.	

Photo 4: Discarded live oysters beneath abandoned farm	
Photo 5: Discarded live oysters beneath abandoned farm	
Photo 6: Abandoned farm with oysters on chaplets.	
Photo 7: Discarded live oysters beneath active permitted farm	

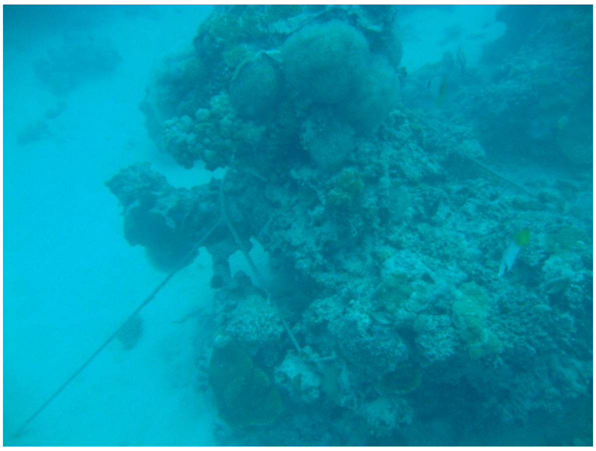
Photo 8: Inactive, non-compliant currently permitted farm. Note biofouling.	
Photo 9: Inactive, non-compliant currently permitted farm.	
Photo 10: Typical anchor rope tie off.	

Photo 11: Example of snapped anchor ropes causing lines to rise to surface.	
Photo 12: Bundled anchor rope disposed in lagoon.	
Photo 13: Sunken lines and dropped live oysters.	

Photo 14: Drum float with live oysters	
Photo 15: Super six asbestos sheeting from collapsed sorting platform on kaoa.	
Photo 16: 60 L drum float	

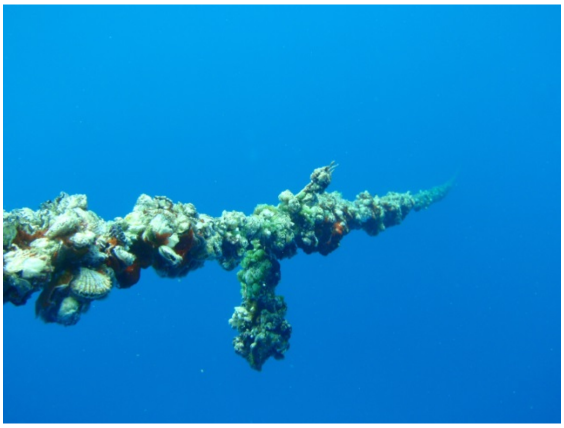
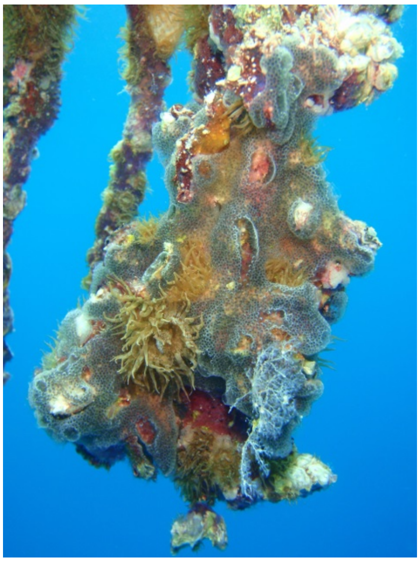
Photo 17: Mainline rope fouling	
Photo 18: Mainline rope fouling	
Photo 19: Inactive non-compliant permitted farm	

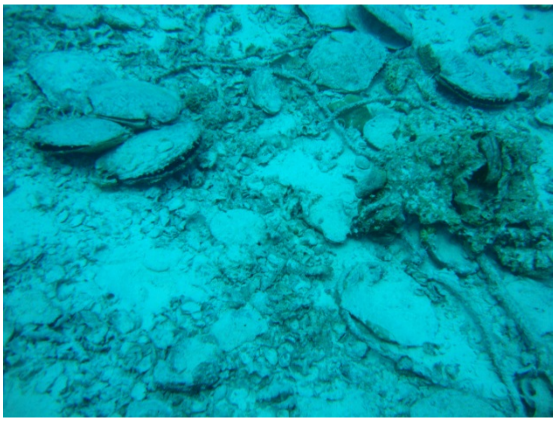
Photo 20: Sunken chaplet lines with fallen live oysters	
Photo 21: Spat sorting platform on derelict farm.	
Photo 22: Typical ABS Float	

Photo 23: Rope bound glass float (very rare)	
Photo 24: Selection of salvaged floats	
Photo 24: Foam boundary marker float	

Photo 24: Open pit rubbish disposal	
Photo 25: Pig farming area that is inundated during king tides.	
Photo 26: Seeding house and accommodation on Kaoa.	

Photo 27: Typical septic tank	
Photo 28: Shell preparation for export.	

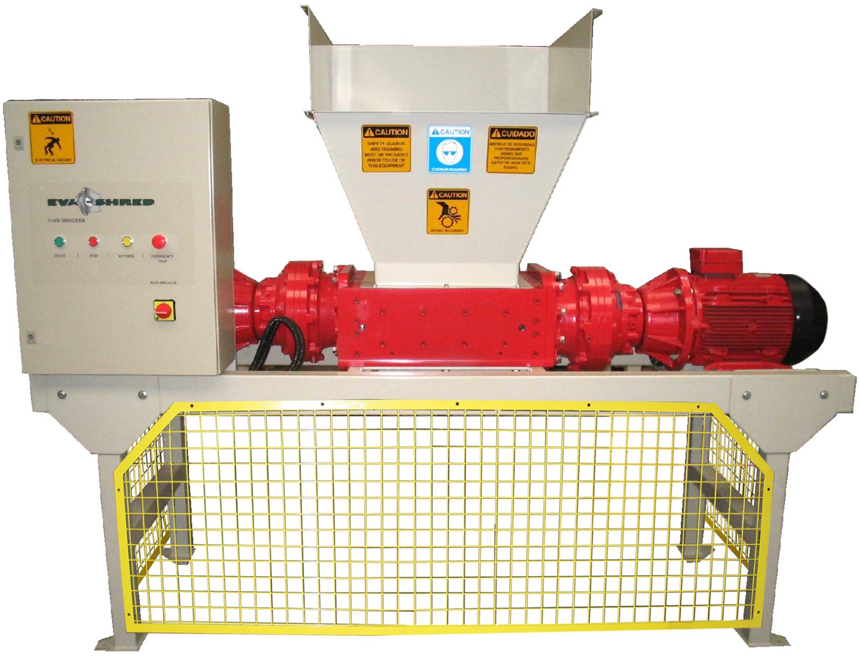
Appendix B – Plastic Chipping Plant Specification

Paper Shredding Computer Hard Drive Shredding

EV45E

PERFORMANCE CHARACTERISTICS:

22 Kw/ 30 Hp Maximum Power
28—30 Rpm Cutter Speed Rotation
10mm, 12mm or 16 mm Shred Width
450 mm x 375 mm Cutting Chamber Opening
18,9 m/min Cutting Speed
1500 Kg per hour*
72 Dba @ 1 meter (no load)
Recommended In-feed: Bin Tipper or Conveyor Belt
Recommended Out-feed: Storage Bin or Conveyor Belt

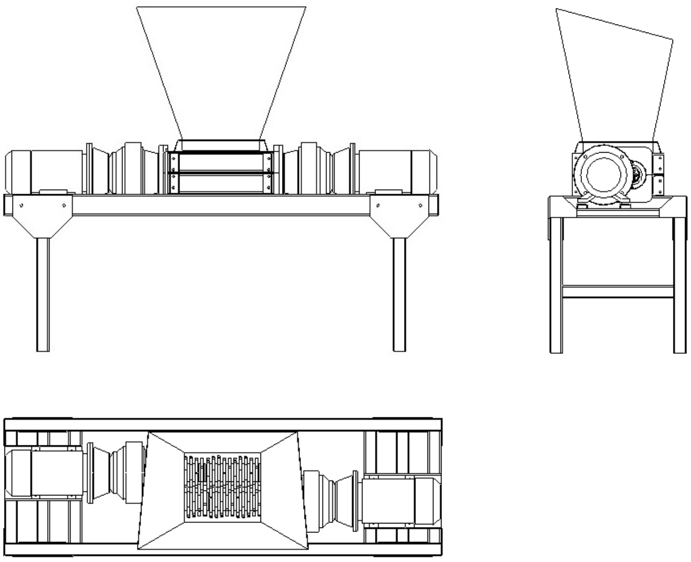


* Normal Office Paper Under Ideal Conditions

Specifications are subject to change without notice. Contact your nearest distributor/ agent for up-to-date specifications prior to purchase.

EV45E

TECHNICAL SPECIFICATIONS:



PHYSICAL DIMENSIONS:

Total Height:	2180 mm
Total Length:	2570 mm
Total Width:	1000 mm
Ground Clearance (underneath shredder):	810 mm
Ground to Hopper Entrance Lip Height:	1815 mm
Hopper Opening:	930 x 800 mm
Shredder Chamber Opening:	450 x 375 mm

SHREDDER NAME:	**EV45E** (Electric)
Number of Motors	2 x 11Kw
Number of Gearboxes Type of Gearboxes	2 Planetary Reduction
Cutter Width No. of Hooks per cutter Cutter Diameter Distance between Shafts Hex Shaft Diameter Critical Shaft Length	10mm, 12mm or 16mm 3 200mm 165mm 77mm AF 450mm
Cutter Chamber Opening Cutting Chamber Height Hopper Height Stand Height Total Height Floor Footprint Dimensions Weight	450mm x 375mm 250mm 1000mm 930mm 2180mm 1000mm x 2570mm 1200 Kg
Capacity/ Throughput Rate	1500 kg per hour*

* Normal Office Paper Under Ideal Conditions

Specifications are subject to change without notice. Contact your nearest distributor/ agent for up-to-date specifications prior to purchase.

Appendix C – Summary of Proposed Diving and Derelict Farming Removal Methodology

Clean-up methodology

Outline

Visual inspections of a number of the abandoned farm sites during February 2015, reveled a range of structures and farm layouts in non- permitted /abandoned sites. Due to the varied nature of these areas and the varied amounts and types of debris, some assumptions need to be made within the cleanup methodology. It has therefore been designed as a guide that will become 'site specific' as work actively progresses throughout the lagoon areas.

Environmental considerations related to the clean-up

Water depth

The Manihiki lagoon is on average 43meters deep. That said much of the farming areas in the abandoned sites are in the shallower ranges of 30 meters and less and commonly less than 20 meters.

Diver safety must be key to this project and as such decompression issues need to be carefully considered. Manihiki is a very remote Island and as such even a relatively minor issue could develop into a life treating situation. As the removal of lines includes cutting the mooring lines from the anchor points , depth limits will need to be addressed and planed closely by the salvage team. Experience in salvage and recovery issues is essential.

Using a remotely operated cutting tool will provide a preferred option for releasing the deeper anchor lines. It must be stated that the clean-up will likely result in short sections of mooring ropes being left on the lagoon floor in the deepest areas i.e. sub 40 m. Such tools will enable the dive team to cut moorings deeper than can be safely done otherwise.

Weather

Generally the lagoon environment is relatively sheltered and as such the weather windows to operate are very good. At times strong wind may limit the days activities.

Timing

The clean-up work should be timed around current farming cycle. Both to reduce the impact of the activity on other lagoon activities but also to ensure that there is adequate labour pool available to assist with any clean-up project.

Available Equipment

Manihiki Island is fairly well equipped and suitable plant is available on the Island to enable a successful clean-up operation:

- Several boats of suitable size are available both privately owner and owned by the Island council.
- The pontoon council boats are recommended for in water stability.
- Dive cylinders and an air compressor are available at the MMR base.
- Excavators and tractors are also available for offloading bulk bags and disposal aspects of the project.

Summary of Derelict Equipment

Floats- There are numerous plastic floats (dominated by Acrylonitrile butadiene styrene (ABS) plastic) on the abandoned farm sites, these floats are moderately to heavily fouled with barnacles and other marine biofouling. Floats recovered during the cleanup will likely make up the largest volume of debris to be removed from the lagoon.

Main lines- In most cases the main lines comprise a single 220 meter length of 10-14mm rope (in some cases can be up to 400meters long) which is supported by floats and secured under tension with mooring lines. The amount of bio fouling found on the mainlines was relatively light on the sunken lines (due to fish predation and poor growing environment). Other areas where the lines are suspended in the water column, the biofouling is heavy.

Mooring / Anchor Lines-Each mainline is secured via mooring lines, both from each end and at regular spacing's along the main line itself. Mooring lines observed during the dive inspections found that the mooring lines tended to be 6-10mm rope and were often tied to coral outcrops at the lagoon floor. For deeper areas concrete filled drums are used as anchor points. These are generally less fouled than the main lines.

Chaplet's- chaptlets were observed both still attached to main lines and dumped on the lagoon floor. Generally 1 meter each in length with stainless steel wires thread through the chaplet ropes .These are connected to the mainline via a short tie, clove hitched or using a shark clip. Some abandoned chaplets were found to still have live oysters still attached. These oyster's will come to a considerable volume and weight.

Collectors-Spat collectors as with the chaplets were noted still attached to the mainlines in mainly abandoned. The collectors were often found to hold live shells and in some cases the shells were of large size and in high numbers .

The collectors are generally either spat collection rope 'pulled loop' or a homemade variation where large diameter rope has been frayed. As with the chaplets the collector ropes are often attached to the mainlines via a small tie.

Live Oysters-Often the diver observed live discarded oysters on the lagoon floor directly beneath the disused main lines. This was especially prevalent under collector lines and sunken lines .Counts of up to 8 shells per square meter and often 5 per square meter were recorded. Even approximate numbers of live shells discarded into the lagoon would be unpractical to establish. It is considered that these live oysters are likely to be a significant contributor to nutrient loading in the lagoon and as such need to be removed.

Other debris- During inspections of sites other debris such as underwater seeding platforms, corrugated iron and general waste materials were noted. These accounted of a very small area but should be considered for removal when come across.

Vomit bags- Vomit bags are a small fine mesh plastic bag and observed only on the shoreline and beaches. It appears that these have been discarded in the water column as they wash up on the lagoon shore. This practice is unacceptable, and needs to be addressed. The entire lagoon shoreline could benefit from a clean-up as there is various plastics and rubbish washed up in most locations inspected.

Locations

For the purposes of this assessment programme it was assumed that the abandoned equipment was present in the areas where concession boundaries were mapped in 1997 and 2011, where areas have not been replaced by current concession permits. This assessment included limited inspection of most of these areas to determine likely volumes of materials.

Due to the historically relaxed nature of the pear farming from the beginning it is likely debris within the lagoon that have become ‘lost’ and are therefore lying outside of mapped concession boundaries. There needs to be consideration for the additional inspections in areas outside current and past know permit sites. Such searches can be easily performed with manta boards and drag lines to efficiently cover large areas. GIS maps are currently available and very good recorded of permitted sites.

Dive inspections revelled that old lines can exist around all of the rorockas and kaoas. Likely due to the easy setup and positioning of farms back before GPS was available.

Typical farm removal process

As many of the abandoned lines still have floats attached the recovery to the surface can be as simply as cutting the moorings to release the mainline and float it to the surface. Prior to this occurring divers should attach any loose ropes found on the lagoon floor to the mooring line so as to recover as much as possible in one go. At the point that the main line has been let-go at one end then the diver(s) can work along the line recovering debris and attaching to the anchor lines as the go. Recovery and mapping of the discarded shells at this time should also be addressed.

Lines will be recovered with Biofouling attached and then cleaned ashore. Cleaning could be undertaken with a line stripper such as used by the mussel marine farming industry, however mobilisation costs are not likely to be cost effective. This unit could then be used by the Islanders for future cleaning on shore.

Lines with Chaplets

If a line to be recovered is found to have chaplets still attached, an ‘on the spot’ assessment whether to remove the chaplets should be made. The construction of chaplets is timely and these can be reused in future by the farmers. Also many of the chaplets were discovered to contain large numbers of live adult oysters ,either still attached via the stainless steel wire or self-seeded onto the chaplet rope. The shells will likely fall off the main line if the rope is recovered into the salvage vessel directly via the mainline. Its very important to recover the live shells from the chaplet’s.

Lines with spat collectors

If a line to be removed is a collector line then it can raised and recovered as one unit .Some collectors were found to be holding large numbers of live oysters. The collector lines will take the most volume during collection. Collectors will need to be brought to land and cleaned / oysters removed. Oysters should destroyed.

Recovery of all debris into the work barge/vessels

There will be a large variance of volume between collector lines and bare main lines. Collector lines will be heavy and contain large amounts of biofouling. These lines could be recovered using a powered roller unit that will enable fast efficient recovery into the recovery vessel .The ropes can be placed into ‘bulk bags’ (such as those available on the island from new spat collector bags) for removal with a loader back at base. The design needs to be light and positioned high to enable easy access.

Once a recovery vessel has filled its bulk bags it can take them shore for offloading using a loader ro excavator.

Appendix D – Lagoon Survey Methodology and Calculations

Overview

This section provides a brief overview of the investigation methodology undertaken as part of the lagoon surveys to determine the type and quantity of derelict material within the lagoon. It also provides the standard assumptions for calculations of derelict farming materials.

Methodology

The methodology employed for the derelict farming equipment comprised the following:

- GIS mapping of 1997 and 2011 pearl farming concessions – for the purposes of this assessment, these were assumed to be the abandoned farming areas, where they were not replaced by current farming concessions;
- Discussions with famers and Manihiki based MMR staff regarding typical pearl farm configurations and equipment;
- Review of the *MMR Manihiki Pearl Industry: 2014 Lagoon Status Report, August 2014;*
- Mapping loaded on to an Ipad to allow ease of navigation and recording of data in the field;
- Review of permitted farm surveys and GIS layers for layouts;
- On land surveys of stored pearl farming equipment;
- Weighing equipment using digital scales. Representative samples of equipment were weighed and averaged to provide a basis from which to calculate weights;
- In lagoon surveys of most abandoned farms to determine layouts and type of equipment present. Where possible, number of lines, length and spacing estimated and layouts recorded. Time constraints did not allow for detailed surveying and measurement pearl farm equipment;
- Photo documenting the types of equipment in the lagoon and ecology;
- Observing lagoon floor and impacts of equipment removal.

Standard Assumptions

The following assumptions were used in the calculations of the equipment quantities:

Item	Assumption
Mainline Rope	0.25 kg/m (weighed average)
Mainline biofouling only	0.050 kg/m (weighed average)
Anchor line rope	0.09 kg/m (weighed average)
Anchor line biofouling only	0.013 kg/m (weighed average)
Spat collectors	0.16 kg/spat collector (clean weighed average)
Spat collector (biofoul and oysters only)	2.16 kg/spat collector (weighed average)
Chaplets	0.08 kg/ chaplet (clean weighed average)
Chaplets (biofoul and oysters only)	1.505 kg/spat collector (weighed average)
Floats	2.02 kg/float (clean weighed average)

Item	Assumption
Floats (Biofoul and oysters only)	2.709 kg/float (clean weighed average)
Oyster	0.32 kg/shell
Mainline length	220 m unless otherwise noted
Anchor rope length	Average depth across farm based upon bathymetry
Anchor line number	1 per 30m mainline length
Spat collector number	1 per 1 m main line where observed
Chaplets number	1 per 1.2m mainline where observed
Float number	1 per 20 m mainline

Abandonded Farms (Estimate Only)

Farm_ID	Name	Area	Synthetic Material																		Organic Material										
			Mainlines				Anchor Lines				Spat Collectors			Chaplets			Total Floats		Synthetic Total	Rope Fouling	Float Fouling	Spat Oyster / Foul		Chaplet oyster / foul		Vomits/rejects			Organic Total		
			Length (m)	Likely Number of Lines	Total Length (m)	Total Weight (kg)	Likely Length / Depth (m)	Likely Number of Lines	Total Length	Total Weight (kg)	Likely Number of meters of spat collectors	Likely number of collectors	Total Weight (kg)	Likely Number of meters of Chaplets	Likely Number of Chaplets	Total Weight (kg)	Number	Total Weight (kg)	kg	kg/total m	Total kg/floats	# of shells	kg/total collectors	# of shells	kg/total chaplets	approx (no/m2 sea floor)	# of shells /total m2	Shell Weight	kg	Total Weight kg	Comments
						0.25				0.09			0.16			0.08		2.02			2.71		2.16		1.51			0.32			
TU186-1	UMURUA TUHE	2.30	180	6	1080	273	10	36	360	31	360	720	115.4	180	144	14	54	109	433	59	146	3391	1555	473	217	1.5	1,620	520	726	1208	
PS165	SAMSON PINIATA	15.90	165	6	990	250	10	33	330	28	2	4	1	2	2	0	49	99	280	54	133	19	9	5	2	3	2,970	953	1140	1465	
HJ220	JOSEPH HIRO	11.00	150	6	900	228	25	30	750	65	3	6	1	1	1	0	45	91	293	55	122	28	13	3	1	3	2,700	867	1044	1373	
KE019	EMILE ALEPHA KAIRUA	14.50	220	2	440	111	10	14	140	12	0	0	0	0	0	0	22	44	123	24	60	0	0	0	0		-	0	84	227	
WJ133	JEAN-MARIE ETAIA TEKAKE WILLIAM	26.60	240	26	6240	1579	15	208	3120	268	3600	7200	1154	240	192	18	312	629	3019	356	845	33914	15552	630	289	4	24,960	8012	9214	12505	
TP247	UNKNOWN	5.10	207	6	948	240	40	31	1240	107	190	379	61	190	152	14	47	95	421	64	127	1786	819	498	228	1.5	1,422	456	648	1100	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced
PT164	TERETIA PINIATA	2.00	207	6	372	94	35	12	420	36	74	149	24	74	59	6	18	36	160	24	49	700	321	195	90	1.5	558	179	252	424	using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat
TT101-2	TIMOTEO TETINI	4.70	207	6	874	221	20	29	580	50	175	349	56	175	140	13	43	87	340	52	117	1646	755	459	210	1.5	1,310	421	589	964	collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is
JP016	PARTY JOHNSON	10.70	207	6	1989	503	20	66	1320	114	398	795	127	398	318	30	99	200	774	118	268	3747	1718	1044	479	1.5	2,983	958	1343	2199	1.5.
PM127	REV.MAURI PAULO	1.90	120	6	720	182	15	24	360	31	240	480	77	50	40	4	36	73	294	41	98	2261	1037	131	60		-	0	139	464	
MT057	TOUMITI MATANGARO	8.10	1480	11	16280	4119	25	542	13550	1165	120	240	38	510	408	38	814	1641	5361	999	2206	1130	518	1339	614	3	48,840	15678	18882	24885	
JD163	DARLING TIAVARE T. JOSEPH	4.40	220	2	440	111	13	14	182	16	50	100	16	50	40	4	22	44	147	25	60	471	216	131	60	0.3	132	42	127	293	
UNKNOWN	No Name allocated (next to 2012 MR277)	7.80	100	2	200	51	30	6	180	15	100	200	32	0	0	0	10	20	98	12	27	942	432	0	0	2	400	128	168	274	
VI013	IOABA TAMATOA VAETERU	7.00	220	5	1100	278	10	36	360	31	660	1320	211	50	40	4	55	111	525	60	149	6218	2851	131	60		-	0	209	784	
CP012-1	POIRI CHARLIE	4.40	220	5	1100	278	10	36	360	31	1100	2200	352	0	0	0	55	111	662	60	149	10363	4752	0	0	4	4,400	1412	1622	2334	
CP012-2	POIRI CHARLIE	3.00	220	4	880	223	15	29	435	37	360	720	115	220	176	17	44	89	392	50	119	3391	1555	578	265	1	880	282	452	882	
TU186-2	UMURUA TUHE	2.80	80	60	4800	1214	15	160	2400	206	6	12	2	0	0	0	240	484	1423	274	650	57	26	0	0	5	24,000	7704	8628	10261	
EM069	MARTIN ELLIS	17.50	220	4	880	223	20	29	580	50	220	440	70	0	0	0	44	89	343	52	119	2073	950	0	0	7	6,160	1977	2149	2528	
MM233	MARK MAREKO	1.90	220	3	660	167		22	0	0	0	0	0	330	264	25	33	67	192	33	89	0	0	866	397	4	2,640	847	970	1195	
PM115-1	MUNOKOAKURA TIANEVA PIHO	2.50	240	2	480	121	30	16	480	41	0	0	0	0	0	0	24	48	163	30	65	0	0	0	0	1	480	154	250	430	
TT006	REV.TEINAKORE TEPANIA	3.90	220	4	880	223	14	29	406	35	0	0	0	0	0	0	22	44	258	50	60	0	0	0	0	0.5	440	141	251		
TB162	BOBBY TARAU	6.10	220	2	440	111	30	14	420	36	1	2	0	0	0	0	22	44	148	28	60	9	4	0	0	2	880	282	370	534	
PP168-2	PINIATA SAMSON PINIATA	7.60	220	7	1540	390		51	0	0	880	1760	282	440	352	33	77	155	705	78	209	8290	3802	1155	530	4	6,160	1977	2264	3046	
TC132	CAROL TEPAANO	3.70	220	2	440	111	10	14	140	12	0	0	0	0	0	0	22	44	123	24	60	0	0	0	0	1	440	141	225	369	
BN138	NOA BAILEY	2.80	207	6	520	132	20	17	340	29	104	208	33	104	83	8	26	52	202	31	70	981	450	273	125	1.5	781	251	352	576	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
WR032	RICALDO TEKAKE WILLIAM	3.90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-	0	0	0	No gear observed
NA003-2	ARTHUR F. NEALE	29.00	165	12	1980	501	30	66	1980	170	660	1320	211	0	0	0	99	200	883	126	268	6218	2851	0	0	1	1,980	636	1030	1986	
VV197		4.01	220	4	880	223	20	29	580	50	440	880	141	0	0	0	23	46	414	52	62	4145	1901	0	0	2	1,760	565	679	1087	
OT158-2	TEMU OKOTAI	2.70	207	6	502	127	25	16	400	34	100	201	32	100	80	8	25	50	201	31	68	945	434	264	121	1.5	753	242	340	561	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
JM010	MAMAKORE MATATIA M. JUBILEE	4.90	220	6	1320	334	10	44	440	38	440	880	141	880	704	66	66	133	579	72	179	4145	1901	2310	1060	2	2,640	847	1099	1738	
DM039-2	MARIE MATARII DONNELLY	2.20	207	6	409	103	25	13	325	28	82	164	26	82	65	6	20	40	164	25	54	770	353	215	98	1.5	613	197	276	455	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
TJ114	JOE TARAEKA	3.80	220	3	660	167	10	22	220	19		0	0	0	0	0	33	67	186	36	89	0	0	0	0		-	0	126	342	
NK131-1	KIMI NEHEMIA	1.00	207	6	186	47	20	6	120	10	37	74	12	37	30	3	9	18	72	11	24	350	161	98	45	1.5	279	89	125	204	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
TT120-1	TOKA TOKA	2.70	180	4	720	182	20	24	480	41	0	0	0	0	0	0	36	73	223	43	98	0	0	0	0	3	2,160	693	834	1087	
TT244-3	TERE TAMATA	10.40	340	8	2720	688	15	90	1350	116	0	0	0	340	272	26	136	274	830	155	369	0	0	893	409	3	8,160	2619	3143	4092	
TT120-2	TOKA TOKA	3.10	220	3	660	167	12	22	264	23	0	0	0	0	0	0	16	32	190	37	43	0	0	0	0		-	0	80	265	
IT212	TEAPA ITAMA	8.60	220	4	880	223	15	29	435	37	220	440	70	220	176	17	44	89	347	50	119	2073	950	578	265	0.4	352	113	282	668	
KJ130	JIMMY KATOA	7.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	No gear observed. Reported to set up on KJ009 instead.
SN209	NUMA SETEPHANO	20.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	Nothing observed from diver tows. MMR suspect that this are was never developed as it is too deep (45-60m)
SR157	RAHUI SAMSON	5.30	220	3	660	167		22	0	0	660	1320	211	0	0	0	33	67	378	33	89	6218	2851	0	0	1.5	990	318	441	852	Lines a long way out ot the area
KP118	PAPAPIA TARAEKA KAISARA	9.30	207	6	1728	437	20	57	1140	98	346	691	111	346	277	26	86	173	672	102	233	3257	1493	908	416	1.5	2,593	832	1167	1911	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
MT199	TEANINI METUASERA	4.90	220	6	1320	334	40	44	1760	151	440	880	141	440	352	33	66	133	659	89	179	4145	1901	1155	530	3	3,960	1271	1539	2242	
TB198	BARBIE TIAITI	2.00	220	2	440	111	25	14	350	30	220	440	70	0	0	0	22	44	212	27	60	2073	950	0	0	2	880	282	369	598	
MP156	PITO MAEVA	2.00	220	4	880	223	15	29	435	37	880	1760	282	0	0	0	44	89	631	50	119	8290	3802	0	0	4	3,520	1130	1299	1930	
RP068	PUPUKE ROBATI JNR	14.60	220	9	1980	501	12	66	792	68	0	0	0	0	0	0	99	200	769	110	268	0	0	0	0	2	3,960	1271	1650	2418	
KT169	TEREKIMIORA KATOA	18.20	220	6	1320	334	15	44	660	57	660	1320	211	0	0	0	66	133	735	75	179	6218	2851	0	0	4	5,280	1695	1949	2684	
TT096	TEPANIA TEPANIA	1.30	207	6	242	61	25	8	200	17	48	97	15	48	39	4	12	24	122	15	33	455	209	127	58	1.5	362	116	164	285	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
TT097	TAUNGA TOKA	17.00	220	20	4400	1113	40	146	5840	502	1540	3080	493	1100	880	83	220	444	2635	298	596	14508	6653	2888	1324	3	13,200	4237	5131	7766	
SS200	SAITU SAITU	2.10	220	1	220	56	25	7	175	15	220	440	70	0	0	0	11	22	163	13	30	2073	950	0	0	3	660	212	255	418	
BD183	DINA BEN	2.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-	0	0	0	Nothing observed
TT101-1	TIMOTEO TETINI	2.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-	0	0	0	empty
TM161	MUNOKOA TEPANIA	4.00	240	2	480	121	20	16	320	28	100	200	32		0	0	24	48	229	28	65	942	432	0	0	1	480	154	248	477	
TM075-2	MERE TUTERU	6.00	220	7	1540	390	25	51	1275	110	1320	2640	423	0	0	0	77	155	1077	94	209	12435	5702	0	0	3	4,620	1483	1786	2864	
TT124	TAUNGA TUTERU	4.60	220	4	880	223	18	29	522	45		0	0		0	0	44	89	356	51	119	0	0	0	0	1	880	282	453	809	
BT182	TOKAMOKOHA BANABA	5.00	220	4	880	223	20	29	580	50	880	1760	282	0	0	0	44	89	643	52	119	8290	3802	0	0	3	2,640	847	1019	1662	
KJ029	JANE KIMI KAINA	6.90	220	8	1760	445	10	58	580	50	1760	3520	564	0	0	0	88	177	1237	97	238	16580	7603	0	0	2	3,520	1130	1465	2701	
TN178	NOA TEANINI	5.20	220	3	660	167	10	22	220	19	440	880	141	0	0	0	33	67	393	36	89	4145	1901	0	0	1	660	212	338	731	
NJ177	JOHNSTON NAPARA	11.90	50	1	50	13	20	1	20	2	50	100	16	0	0	0	2	4	34	3	5	471	216	0	0	3	150	48	56	91	
NA003-1	ARTHUR F. NEALE	13.60	440	3	1320	334	15	44	660	57	0	0	0	660	528	50	66	133	573	75	179	0	0	1733	795	5	6,600	2119	2373	2946	Platfrom for shell collection. Made of pvc pipes. Numerous discarded shells.
ST185	TOTOO SETEPHANO	13.40	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		-	0	0	0	No lines observed
NC153	CHRISTINE HAUMATA NEWNHAM	10.40	220	1	220	56	15	7	105	9	0	0	0	0	0	0	11	22	87	12	30	0	0	0	0	2	440	141	184	270	
TT244-1	TERE TAMATA	2.60	220	2	440	111	20	14	280	24	50	100	16	75	60	6	22	44	201	26	60	471	216	197	90	2	880	282	368	569	
TT244-2	TERE TAMATA	1.10	220	2	440	111	20	14	280	24	50	100	16	75	60	6	22	44	201	26	60	471	216	197	90	1	440	141	227	428	
MH201-1	HAUMATA MANAVAROA	3.30	220	4	880	223	25	29	725	62	220	440	70	0	0	0	44	89	444	54	119	2073	950	0	0	3	2,640	847	1021	1465	
MS215	SHARON MARSTERS	5.10	207	6	948	240	10	31	310	27	190	379	61	190	152	14	47	95	436	52	127	1786	819	498	228	1.5	1,422	456	636	1072	Assumptions made due to lack of data: Average value used for length and likely number of lines; total length deduced using area multiplied by average length per hectare of recorded lengths (185.859 metres); metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.
PA076	ABRAHAM A. PAU	5.20	280	5	1400	354	35	46	1610	138	1100	2200	352	0	0	0	70	141	986	92	190	10363	4752	0	0	2	2,800	899	1180		
KA102	AKEAU KAIRUA	15.60	220	3	660	167	22	22	484	42	100	200	32	100	80	8	33	67	315	40	89	942	432	263	120	1	660	212	341	656	
	Tukao Bay Unknown #1	2.96	185	8	1480	374	15	49	735	63	0	0	0	0	0	0	74	149	587	84	201	0	0	0	0	1	1,480	475	760	1347	
	Tukao Bay Unknown #2	1.48	100	7	700	177	10	23	230	20	0	0	0	0	0	0	35	71	267	38	95	0	0	0	0	1	700	225	358	625	
	Tukao Bay Unknown #3	0.59	100	6	600	152	10	20	200	17	100	200	32	100	80	8	30	60	269	33	81	942	432	263	120	1	600	193	307	576	
	Tukao Bay Unknown #4	1.48	210	6	1260	319	10	42	420	36	80	160	26	0	0	0	63	127	508	69	171	754	346	0	0	1	1,260	404	644	1152	
	Tukao Bay Unknown #5	1.50	90	3	270	68	10	9	90	8	0	0	0	0	0	0	13	26	102	15	35	0	0	0	0	1	270	87	137	239	
	Total	443				21,800			56,045	4,820			7,074			585	4,243	8,554	36,888	5,083	11,497	207,962	95,366	20,496	9,399		222,399	71,390	87,970	124,591	
	Average	6.74	206.80	5.56	1196.76	302.78																									

Average total meters per Ha 177.5463

Rope Total 34,279

Number of Shells 450,857

Biofoul total 192,734 16,580

Oyster total 176,155

Saleable oytsters 88,077

Inactive Permited Farms Likey to be Abandonded in March 2015 (Estimate Only)

		Synthetic Material: Mainlines				Anchor Lines				Spat Collectors			Chaplets			Total Floats		Synthetic Total	Organic Material: Rope Fouling	Float Fouling	Spat Oyster / Foul		Chaplet oyster / foul		Vomits/rejects			Organic Total		
Farm_ID	Name	Length (m)	Likely Number of Lines	Total Length (m)	Total Weight (kg)	Likely Length / Depth (m)	Likely Number of Lines	Total Length	Total Weight (kg)	Likely Number of meters of spat collectors	Likely number of collectors	Total Weight (kg)	Likely Number of meters of Chaplets	Likely Number of Chaplets	Total Weight (kg)	Number	Total Weight (kg)	kg	kg/total m	Total kg/floats	# of shells	kg/total collectors	# of shells	kg/total chaplets	approx (no/m2 sea floor)	# of shells /total m2	Shell Weight	kg	Total Weight kg	Comments
					0.25				0.09			0.16			0.08		2.02			2.71		2.16		1.51			0.32			
KH023	Reni Teresa Kaina	200	9	1800	455	45	60	2700	232	360	720	115.4	360	288	27	90	181	1011	126	244	3391	1555	945	433	1.5	2,700	867	1236	2122	
TC290	Catherine Tobia	40	4	160	40	25	5	125	11	32	64	10.3	32	25.6	2	8	16	80	10	22	301	138	84	39	1.5	240	77	108	179	
KL166	Luka Kaitara	240	19	4560	1154	20	152	3040	261	912	1824	292.2	912	729.6	68	228	460	2235	270	618	8592	3940	2394	1098	1.5	6,840	2196	3083	5049	
KN268	Nehemia Kaina	200	2	400	101	20	13	260	22	80	160	25.6	80	64	6	20	40	196	24	54	754	346	210	96	1.5	600	193	270	442	
KT021	Tobia Kaitara	80	19	1520	385	20	50	1000	86	304	608	97.4	304	243.2	23	76	153	744	90	206	2864	1313	798	366	1.5	2,280	732	1028	1682	
ST027	Trainee Samson	220	13	2860	724	30	95	2850	245	572	1144	183.3	572	457.6	43	143	288	1483	181	387	5389	2471	1502	689	1.5	4,290	1377	1946	3248	
MM091	Munokoa Maea	80	5	400	101	20	13	260	22	80	160	25.6	80	64	6	20	40	196	24	54	754	346	210	96	1.5	600	193	270	442	
MR107	Rino Tangi Mareko	200	8	1600	405	20	53	1060	91	320	640	102.5	320	256	24	80	161	784	95	217	3015	1382	840	385	1.5	2,400	770	1082	1771	
MT034	Terepai Matangaro	80	1	80	20	20	2	40	3	16	32	5.1	16	12.8	1	4	8	38	5	11	151	69	42	19	1.5	120	39	54	87	
PH140	Henry Puna	150	30	4500	1139	15	150	2250	194	900	1800	288.4	900	720	68	225	454	2142		610	8479	3888	2363	1084	1.5	6,750	2167	2776	4918	
PT077	Tuatai Piniata	220	6	1320	334	10	44	440	38	264	528	84.6	264	211.2	20	66	133	609	72	179	2487	1140	693	318	1.5	1,980	636	887	1424	
RK195	Kumi Ripata	100	10	1000	253	10	33	330	28	200	400	64.1	200	160	15	50	101	461	55	135	1884	864	525	241	1.5	1,500	482	672	1078	
RT022	Tarau Kaina	200	2	400	101	30	13	390	34	80	160	25.6	80	64	6	20	40	207	25	54	754	346	210	96	1.5	600	193	272	453	
RT265	Totoo Tatahua Ripata	100	4	400	101	20	13	260	22	80	160	25.6	80	64	6	20	40	196		54	754	346	210	96	1.5	600	193	247	442	
SL078	Lazaro Samson	35	10	350	89	20	11	220	19	70	140	22.4	70	56	5	17	34	169	21	46	659	302	184	84	1.5	525	169	235	384	
TN288	Ngatamaine Teitinga	60	2	120	30	25	4	100	9	24	48	7.7	24	19.2	2	6	12	61		16	226	104	63	29	1.5	180	58	74	135	
TR117	Ravengakore Tuteru	200	11	2200	557	15	73	1095	94	440	880	141.0	440	352	33	110	222	1047	125	298	4145	1901	1155	530	1.5	3,300	1059	1483	2404	
MT034	Terepai Matangaro	80	1	80	20	20	2	40	3	16	32	5.1	16	12.8	1	4	8	38	5	11	151	69	42	19	1.5	120	39	54	87	
RT265	Totoo Tatahua Ripata	350	2	700	177	15	23	345	30	140	280	44.9	140	112	11	35	71	333	40	95	1319	605	368	169	1.5	1,050	337	472	765	
TU186	Umurua Tuhe	100	14	1400	354	15	46	690	59	280	560	89.7	280	224	21	70	141	665		190	2638	1210	735	337	1.5	2,100	674	864	1529	
TT018	Teinaki Toka	400	16	6400	1619	25	213	5325	458	1280	2560	410.2	1280	1024	96	320	645	3228	393	867	12058	5530	3361	1541	1.5	9,600	3082	4341	7177	
TT096	Tepania Tepania	120	4	480	121	20	16	320	28	96	192	30.8	96	76.8	7	24	48	235	28	65	904	415	252	116	1.5	720	231	325	531	
WS047	Wade Paul Vaetoru	150	1	150	38	10	5	50	4	30	60	9.6	30	24	2	7	14	68		19	283	130	79	36	1.5	225	72	91	159	
WP002	Papa Tohutohu Williams	200	24	4800	1214	35	160	5600	482	960	1920	307.6	960	768	72	240	484	2559	315	650	9044	4147	2521	1156	1.5	7,200	2311	3277	5521	
SL078	Lazaro Samson	200	1	200	51	25	6	150	13	40	80	12.8	40	32	3	10	20	99		27	377	173	105	48	1.5	300	96	123	223	
ET272	Thomas Elisa	220	1	220	56	20	7	140	12	44	88	14.1	44	35.2	3	11	22	107	13	30	415	190	116	53	1.5	330	106	149	243	
PR198	Roimata Samson	80	2	160	40	20	5	100	9	32	64	10.3	32	25.6	2	8	16	78	9	22	301	138	84	39	1.5	240	77	108	177	
KN268	Nehemia Kaina	200	2	400	101	20	13	260	22	80	160	25.6	80	64	6	20	40	196	24	54	754	346	210	96	1.5	600	193	270	442	
PT077	Tuatai Piniata	200	19	3800	961	20	126	2520	217	760	1520	243.5	760	608	57	190	383	1862		515	7160	3283	1995	915	1.5	5,700	1830	2345	4206	
PT084	Tamaroa Pokipoki	280	3	840	213	20	28	560	48	168	336	53.8	168	134.4	13	42	85	412	50	114	1583	726	441	202	1.5	1,260	404	568	930	
TR256	Ruhau Granny Tamaunu	130	10	1300	329	20	43	860	74	260	520	83.3	260	208	20	65	131	637	77	176	2449	1123	683	313	1.5	1,950	626	879	1439	
PT287	Tereapii Paulo	100	6	600	152	25	20	500	43	120	240	38.5	120	96	9	30	60	303		81	1130	518	315	144	1.5	900	289	370	673	
MJ289	John Matangaro	220	3	660	167	20	22	440	38	132	264	42.3	132	105.6	10	33	67	324	39	89	1244	570	347	159	1.5	990	318	446	731	
	Total				11,603			34,320	2,952			2,939			688	2,292	4,621	22,802	2,114	6,210	86,405	39,623	24,082	11,043		68,790	22,082	30,406	51,094	

Comments: Assumptions made due to lack of data: Values measured off map for length and likely number of lines; total length was deduced from total number of lines that need to be removed; metreage of chaplets/spat collectors is equal to 20% of total length; depth is taken from seabed map; approx number of reject shells per m2 is 1.5.

Total Ropes 18,181

Biofoul total 81,072
Oyster total 72,748
Saleable oytsters 36,374

Active Permitted Farms - Equipment Requiring Removal to Make Compliant (Estimate Only)

			Synthetic Material											
			Mainlines				Anchor Lines				Spat Collectors		
Farm_ID	Name	Area	Length (m)	Likely Number of Lines	Total Length (m)	Total Weight (kg)	Likely Length / Depth (m)	Likely Number of Lines	Total Length	Total Weight (kg)	Likely Number of meters of spat collectors	Likely number of collectors	Total Weight (kg)
						0.25				0.09			0.16
CIPLF	CIPLF		220	30	6600	1670	25	220	5500	473	1320	2640	423.0
CIPLF	CIPLF		380	4	1520	385	25	50	1250	108	304	608	97.4
JM098	Mataio & Rangi Johnson		220	6	1320	334	30	44	1320	114	264	528	84.6
KB030	Bernadino Boaza Kaina		200	5	1000	253	25	33	825	71	200	400	64.1
TT052	Tangi Toka		200	2	400	101	20	13	260	22	80	160	25.6
KJ009	John Koteka Snr & John Koteka Jnr		170	9	1530	387	20	51	1020	88	306	612	98.1
OT158	Unknown		150	15	2250	569	20	75	1500	129	450	900	144.2
ME046	Emil Numangatini Murray		220	3	660	167	20	22	440	38	132	264	42.3
JM098	Mataio & Rangi Johnson		200	5	1000	253	15	33	495	43	200	400	64.1
	Total					4,119			12,610	1,084			1,043

		Synthetic Material						Organic Material										
		Chaplets			Total Floats		Synthetic Total	Rope Fouling	Float Fouling	Spat Oyster / Foul		Chaplet oyster / foul		Vomits/rejects			Organic Total	
Farm_ID	Name	Likely Number of meters of Chaplets	Likely Number of Chaplets	Total Weight (kg)	Number	Total Weight (kg)	kg	kg/total m	Total kg/floats	# of shells	kg/total collectors	# of shells	kg/total chaplets	approx (no/m2 sea floor)	# of shells /total m2	Shell Weight	kg	Total Weight kg
				0.08		2.02			2.71		2.16		1.51			0.32		
CIPLF	CIPLF	1320	1056	99	330	665	3330	405	894	12435	5702	3466	1589	1.5	9,900	3178	4477	7402
CIPLF	CIPLF	304	243.2	23	76	153	765	93	206	2864	1313	798	366	1.5	2,280	732	1031	1703
JM098	Mataio & Rangi Johnson	264	211.2	20	66	133	552	84	179	2487	1140	693	318	1.5	1,980	636	898	1499
KB030	Bernadino Boaza Kaina	200	160	15	50	101	504	61	135	1884	864	525	241	1.5	1,500	482	678	1121
TT052	Tangi Toka	80	64	6	20	40	196	24	54	754	346	210	96	1.5	600	193	270	442
KJ009	John Koteka Snr & John Koteka Jnr	306	244.8	23	76	153	749	91	206	2883	1322	803	368	1.5	2,295	737	1033	1692
OT158	Unknown	450	360	34	112	226	1102	133	303	4239	1944	1181	542	1.5	3,375	1083	1520	2489
ME046	Emil Numangatini Murray	132	105.6	10	33	67	324	39	89	1244	570	347	159	1.5	990	318	446	731
JM098	Mataio & Rangi Johnson	200	160	15	50	101	475		135	1884	864	525	241	1.5	1,500	482	617	1092
	Total			244	813	1,639	7,997	929	2,203	30,673	14,066	8,549	3,920		24,420	7,839	10,971	18,172

total rope 6,491

Biofoul total 28,957
Oyster total 25,825
Saleable oytsters 12,912

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		Name	Signature	Name	Signature	Date
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