REPORT ON THE FINDINGS OF SUB-TIDAL SAMPLING SURVEYS OF GREEN LIPPED MUSSEL POPULATIONS IN ŌHIWA HARBOUR 2016

For the Ōhiwa Harbour Strategic Coordination Group (OHSCG) and Te Ūpokorehe Resource Management Team

Prepared by
MUSA Dive – Marine and Environmental Services

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EXECUTIVE SUMMARY

This report brings together the results from the sub-tidal sampling of Kūtai, *Perna canaliculus*, Green Lipped Mussel and Pātangaroa, *Coscinasterias muricata,* Eleven-armed Sea star in Ōhiwa harbour 2016. The report provides a narrow representation of the distribution, abundance and sizing of the identified species.

The sub-tidal marine research sampling surveys were conducted in two parts. Part one included the qualitative approach which utilised mātauranga Māori or customary knowledge information shared by Te Ūpokorehe Hapū. The information shared, included the identification of traditional mussel bed boundary areas in the eastern side of the harbour. Part two built on from part one and included the quantitative approach using marine science research methods in the field.

Sub-tidal dive sampling surveys and distribution mapping were conducted in the eastern and western sides of Ōhiwa harbour between the months of April-August 2016. A total of eighty (80) quarat (0.25m² and 1m²) samples were undertaken with one hundred and thirty-four (134) dive marks recorded.

In 2007 there were an estimated one hundred and twelve (112) million mussels present in the western side of the harbour. In 2016 there were an estimated five hundred and forty-three thousand, nine hundred and forty-two mussels (543,942) recorded in all areas of Ōhiwa harbour. In 2009 there were an estimated one point two million (1.2) seastars in the mussel bed boundaries of the harbour. In 2016 there were an estimated four thousand, seven hundred and twenty-one (4,721) seastars recorded in the mussel beds.

In 2016, it was found that a significant ninety-nine point six percent (99.6%) of the original 2007 mussel population in the western side of the harbour were no longer present. In the eastern side of the harbour it was found that two of the three identified traditional bed areas recorded mussels as no longer present.

Recommendations that arise from the findings of this report include; continued monitoring of mussel populations in the harbour; development of a best practice seastar management plan and; development of a practical technical design for the restoration of mussel populations inclusive of mātauranga Māori alongside western science, in Ōhiwa harbour.

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1.0 PURPOSE

1.1 The purpose of this report was to provide information on the sub-tidal sampling of identified customary taonga[1] marine invertebrate species in Ōhiwa harbour.

1.2 The purpose of the sub-tidal sampling surveys was to provide evidence based information on the 'health' or state of identified species in the harbour.

1.3 The identified species include; Kūtai, *Perna canaliculus*, Green Lipped Mussels and Pātangaroa, *Coscinasterias muricata,* Eleven-armed Seastar.

2.0 AIM

2.1 The aim of the sub-tidal surveys was to assist the relevant authorities in the wise use, care and sustainable management of the identified taonga species for present and future generations.

3.0 OBJECTIVES

3.1 The objectives of the sub-tidal surveys was to ascertain the current distribution, abundance and sizing of the identified species in the eastern and western sides of the harbour.

4.0 BACKGROUND

4.1 In 2007, 2008, 2009 & 2013 sub-tidal sampling surveys of the identified species were conducted in the western side of Ōhiwa Harbour.

[1] Taonga species can be described as those species which have been harvested by generations of Māori. They are considered customary species as traditional knowledge pertaining to the fishing practices and protocols of specific species such as; when to harvest, how to harvest, preparation for eating and storing and the environmental signs and conditions that exist around harvesting, are still actively practised and understood by contemporary Māori descendants (Paul-Burke, 2015).

4.2 The research identified significantly decreasing mussel bed populations and associated bed boundaries in the western side of the harbour.

4.3 The voracious green lipped mussel predator, *Coscinasterias muricata* or eleven-armed seastar was identified as significantly present.

4.4 In 2016, evidence based information regarding the distribution, abundance and sizing of green lipped mussel populations in the western side of the harbour was no longer current.

4.5 The distribution, abundance and sizing of green lipped mussel populations in the eastern side of the harbour was unknown.

4.6 There was also no evidence based information on the current mussel bed populations in the eastern side of the harbour.

4.7 Te Ūpokorehe Resource Management Team strongly support the establishment of sub-tidal evidence based research to ascertain the current health of traditional customary mussel populations in the eastern side of the harbour.

4.8 The proposed sub-tidal survey is strongly aligned with Te Ūpokorehe Iwi Management Plan (2012) under the heading of Coastal Management Fisheries, Water and Recreational Policies (pp.38-39), which seeks to;

- Provide Te Ūpokorehe with a clear picture of the health of the water.
- Monitor the fish stocks within the rohe.
- Advocate for the protection of existing stock.
- Be involved in monitoring the effects of shellfish beds, habitat restoration and enhancement.
- To be involved in all issues relating to Ōhiwa Harbour.

4.9 The proposed sub-tidal survey is strongly aligned with Te Rūnanga o Ngāti Awa – *Te Ara Poutama o Ngāti Awa: Strategic Pathways to the Future 2010-2015* under the Strategic Principle of Kaitiakitanga (p.8) which advocates;

- To protect the culture, environment, resources and people in accordance with Ngāti Awa cultural practices.
- Enhance mauri of natural resources within the Ngāti Awa Takiwa.
- Promote the efficient use of resources for environmental management.
- Active exercise of Ngāti Awatanga and mana whenua within the takiwa of Ngāti Awa.
- Managing customary fisheries resources in accordance with customary practices and fisheries regulations.
- Sustain and enhance Ngāti Awa customary fisheries resources.

4.10 The proposed sub-tidal surveys are further aligned with the Ōhiwa Harbour Strategy (Refreshed) 2014: Action Area 2 – Harbour Management (p.21) which asserts;

- Kaimoana in the Ōhiwa Harbour is threatened by overfishing, inappropriate gathering, starfish predation, and barriers to fish spawning.
- If the shellfish species within the harbour are not monitored, collected or managed correctly, they can decline and disappear from the harbour.
- Ongoing research is necessary and this should take more of a bicultural focus.

5.0 RESEARCH DESIGN

5.1 The sub-tidal marine sampling surveys were conducted in two parts.

5.2 Part one included the qualitative approach - mātauranga Māori interviews for the eastern side of the harbour.

5.3 Part two included the quantitative approach - marine science field research for the eastern and western sides of the harbour.

6.0 PART ONE: QUALITATIVE APPROACH - MĀTAURANGA MĀORI

6.1 For the purposes of this project, mātauranga Māori can be described as a complex and dynamic body of knowledge originating from Māori ancestors, which adapts and changes but does not lose its integrity nor sense of origin.

Mātauranga is often localised knowledge which is grounded in a particular place and sets of understandings and experiences that are generated by the people – whānau, hapū, iwi, who have occupied and interacted with that place and its environs for many consecutive generations. Mātauranga is holistic, inter-disciplinary and inter-generational. It includes Māori world views, language, perspectives, principles, ethics and cultural practices[2].

6.2 MUSA Dive marine and environmental field research projects incorporate mātauranga Māori alongside western marine science field research methods. An example includes, all physical field sampling areas (actual dive site commencement locations) being determined by local (hapū/iwi) knowledge experts.

6.3 This design approach is supported by Dovers & Hussey (2013) when they assert that indigenous knowledge and understandings of the natural world, has made substantial contributions to western science and produced succinct knowledge and observational data sets promoting 'environmental integrity' and sustainability of the world, its ecosystems and natural resources.

There is a wealth of traditional accumulated knowledge in Māori and indigenous cultures which is intimately bound to being in one place for many generations[3] .

6.4 The aim of the sub-tidal sampling surveys highlights the need to capture marine information outcomes that provide the relevant stakeholders with useful data that can inform future policy and management practices. Durie (2004) refers to this approach as 'research at the interface.'

[2] Paul-Burke, 2016
[3] Cheung, 2008; Paul-Burke, 2011, 2015

As there are clear benefits to be gained in combining traditional and contemporary methodologies, qualitative and quantitative, to provide improved outcomes for the Ōhiwa Harbour Implementation Forum, whanau, hapū, iwi and Ōhiwa harbour.

6.5 In March 2016, a semi-structured, small group focus interview with participating representatives from Te Ūpokorehe was conducted aboard the research vessel MUSA as part of a boat field trip on the eastern side of the harbour.

6.6 The purpose of the boat field trip was to ascertain the traditional distribution boundaries, areas of the identified species, including prioritisation of dive sampling efforts.

6.7 This method is consistent with the baseline surveys conducted in the western side of the harbour in 2007. Whereby, Ngāti Awa iwi representatives were taken by boat to identify the traditional start and end boundaries for the customary species including the prioritisation of sites for sampling. Information from the qualitative interview identified the start and end boundaries of physical dive sites for baseline sampling.

6.8 In August 2016, hapū/iwi representatives from Te Ūpokorehe assisted in the collation and recording of GPS mapping coordinates and field sampling methods aboard the researcher's vessel in the eastern side of the harbour.

7.0 PART TWO - QUANTITATIVE MARINE SCIENCE FIELD RESEARCH METHODS

7.1 A total of one hundred and thirty-four (134) sub-tidal dive marks were recorded across all sites surveyed between the months of April-August 2016.

7.2 Mātauranga pertaining to the traditional distribution boundaries identified by Te Ūpokorehe (2016) and Ngāti Awa (2007)[4] representative's determined the commencement of all sub-tidal mapping and sampling in the eastern and western sides of the harbour.

[4] Paul-Burke, 2007, 2009; Paul-Burke & Burke, 2013, 2015; Paul-Burke, 2015.

7.3 The purpose of the sub-tidal sampling of the identified species was based on the need to capture quantitative data using accepted western marine science research techniques and methods.

7.4 Each of the identified species for this sampling project (green lipped mussels and eleven-armed seastars) required different survey sample methods. The sample methods utilised for individual species dictate that both biotic and abiotic factors be taken into consideration.

7.5 Factors for consideration included; how species position themselves within the environment (in group clusters, individually, widely dispersed); sizing considerations for measurements, the dynamics of swell, visibility, fine sand sediments and tidal flow conditions.

8.0 MAPPING TRADITIONAL AND CONTEMPORARY MUSSEL BED BOUNDARY AREAS - GPS (GEOGRAPHICAL POSITIONING SATELLITES) COORDINATES

8.1 All local knowledge sites surveyed were marked using WGS84 marine GPS system. This was to ensure the accurate recording of identified sites for future replication monitoring surveys and for comparability purposes[5].

8.2 For the purposes of this study, a fixed GPS system (attached to the main dive boat) and a backup hand held GPS system were used to locate sites of significance.

8.3 For the purposes of this project the under-water size and shapes of contemporary mussel bed distribution boundary areas were marked and mapped utilising GPS coordinates and under-water distribution mapping methods[6] consistent with previous baseline and monitoring programs conducted in the western side of the harbour.

[5] MacDiarmid, 2008; Morrison, 1996; Kilner & Ackroyd, 1982; Freeman, 2006; Paul-Burke, 2007.
[6] Paul-Burke, 2007; Burke, 2009; Paul-Burke & Burke, 2013.

8.4 It was anticipated that the traditional distribution ranges of green lipped mussel populations identified by participating hapū representatives would inform the dive commencement location areas.

8.5 Upon the identification of mussel population presence in the eastern side of the harbour, the logistics pertaining to the systematic mapping of under-water mussel bed boundaries were able to be determined and employed.

8.6 To work safely, efficiently and to the unique conditions required for all species the most appropriate dive survey techniques pertaining to the individual species were utilised for the proposed sub-tidal baseline sampling surveys.

9.0 KŪTAI, *Perna canaliculus*, GREEN LIPPED MUSSEL – SAMPLING METHODS

9.1 For the purposes of this project the sampling of mussel populations in the eastern and westerns sides of the harbour was achieved utilising two appropriate marine science sampling methods.

9.2 The first sampling method in identified sites utilising the haphazard sampling technique[7] of randomly placing 0.25m x 0.25m quadrats within the identified mussel bed boundary areas[8].

9.3 With each quadrat placement all individuals were measured and counted. Pre-determined size classes were used. The collated data provided evidence based information pertaining to abundance, density and sizing of mussel populations.

9.4 The second sampling method utilising the random placement of a 1m x 1m quadrat to provide percentage assessment of mussel coverage in identified bed boundary areas.

9.5 The second sampling method (1m x 1m quadrat) was conducted during the seastar sampling surveys.

[7] MacDiarmid, 2008; McLeod, 2009; Morrison, 1996.
[8] Kilner & Ackroyd, 1982; Paul-Burke & Burke, 2013.

The collated data will assist statistical analysis for mussel coverage in correlation with seastar density.

9.6 For the purposes of this study all measurements of mussels conducted in the wild, were taken across the widest part of the shell as opposed to the more traditional measurement of farmed mussels which utilise shell length. Measuring across the widest area of the posterior end of the mussels was utilised in an attempt to inflict as minimal an impact on the mussels as possible[9].

10.0 PĀTANGAROA, *Coscinasterias muricata*, ELEVEN-ARMED SEASTAR – SAMPLING METHODS

10.1 For the purposes of this project the sampling of seastars was conducted inside and outside of identified mussel bed boundary areas. The sampling of seastars utilised two sampling methods.

10.2 The first sampling method utilised the systematic sampling technique[10] involving kick cycles[11] and the systematic placement of a 1m x 1m quadrat[12] five times (5x) within identified mussel bed boundary areas.

10.3 All seastars were identified (there are three or more differing species of known seastars in Ōhiwa harbour) and counted. Measurements of seastar diameter were taken using pre-determined size classes.

10.4 Percentage coverage of green lipped mussels within the 1m x 1m quadrat were also undertaken using 5% increments (nil, 5%, 10%, 15% up to 100%).

10.5 The collated data for the first sampling method provided evidence based information pertaining to seastar abundance and density; and the statistical significance in correlation with mussel coverage.

[9] Paul-Burke, 2007.
[10] Kaiser *et al*, 2011; Morrison, 1996.
[11] PADI, 2004; Paul-Burke & Burke, 2010.
[12] Kilner & Ackroyd, 1982.

11.0 DATA ANALYSIS

11.1 Data from mussel sampling surveys conducted in 2007, 2008, 2009, 2013 and the separate seastar sampling surveys in 2009 and 2013 were used as baselines with which to compare population numbers and cohort sizing in the western side of the harbour.

11.2 Data from mussel sampling surveys in 2016 were used to construct a baseline of population numbers, distribution and cohort sizing in the eastern side of the harbour.

11.3 Geographical information systems (GPS) mapping for sub-tidal mussel bed boundaries were mapped to a high resolution and mussel samples within the identified bed boundaries were counted and measured[13].

All mapped mussel areas were equally sampled. Data analysis was achieved using Microsoft Excel, PivotTable and PivotChart.

11.4 Size frequency distributions were calculated by adding individual samples together within each identified area. The data was analysed by collating the total number of mussels sampled per the identified mussel bed areas.

11.5 The mean number of mussels per quadrat sample was applied to determine the statistical significance of the data. Sample populations were graphed by size and distribution within the mussel bed areas.

11.6 Population density numbers were estimated by totalling the number of mussels sampled. This was then divided by the total number of quadrats used, to give an average of mussels per quadrat.

11.7 For quadrats that were 0.25 of a metre the average was multiplied by four to give an average number of mussels per square metre. The total was then multiplied by the total number of metres in all sites combined.

11.8 Measurements for identified bed boundaries were achieved by measuring distances between GPS marks on the boundaries of the mussel beds.

[13] Morrison, 1996; Aswani & Lauer, 2006; Paul-Burke, 2015

11.9 The mean average length and width of each site was multiplied together to identify the total square metres of each identified site within the mussel bed boundaries.

This calculation was also used to identify present and no longer present bed boundaries within each site (against the original 2007 bed boundaries for the western side).

11.10 Identification of metres per each site with mussels present was calculated by dividing the remaining square metres of each by the total square metres, giving the percentages of mussel bed boundaries both present and no longer present.

11.11 Data from each yearly total of species counts were converted to density/sq m. The numbers were then multiplied by the area surveyed in that year and converted into numbers (thousands) present.

11.12 The 95% confidence interval for each Total estimate was then calculated to enable the use of error bars. Each yearly total number was tested against the next year's total using an independent two samples T Test[14] with unequal variance.

11.13 P values less than 0.05 were considered significant.

12.0 RESULTS

12.0.1 Sub-tidal dive sampling surveys and distribution mapping was conducted in the eastern and western sides of Ōhiwa harbour between the months of April-August 2016.

12.0.2 A total of eighty (80) quadrat samples (0.25m² and 1m²) were conducted and one hundred with a total of one hundred and thirty-four (134) dive marks recorded.

[14] Sokal & Rohlf, 1995.

Figure 1. Map of all dive marks (blue flags) in Ōhiwa Harbour April-August 2016 (Imaging by Paul-Burke, 2016).

12.1 *Mussel Distribution Western Side*

In 2016, it was found that mussel distribution bed boundaries had altered significantly in the western side of Ōhiwa harbour. In 2007 the original mussel bed boundaries in the western side of the harbour (Fig 2) covered a total of one hundred and ninety-four thousand square metres (194,000 sq.m). In 2013 the mussel bed boundaries recorded a total area of twenty-three thousand square metres (23,000 sq.m).

In 2016 two separate mussel beds were recorded in the former 1B and 1C sites of the original 2007 bed. The new 1B bed covered a total of two thousand, three hundred and forty-two square metres (2342 sq.m). The new 1C bed recorded a total are of nine thousand, four hundred and sixty square metres (9460 sq.m). The total area of mussel presence in the western side of the harbour in 2016 was eleven thousand, eight hundred and two square metres (11,802 sq.m). In 2016 it was found that an alarming ninety-four percent (94%) of the original bed boundaries in the western side of the harbour were no longer present (Fig 2).

Figure 2. The original 2007 mussel bed boundaries (unshaded black area). The 2013 mussel bed boundary area (black stripes). The new 2016 mussel bed areas (yellow stripes) identifying significantly reduced distribution range in the western side of Ōhiwa harbour (Imaging by Paul-Burke, 2016).

12.1.2 *Mussel Distribution Eastern Side*

In the eastern side of the harbour, three sites (Fig 3) were identified as traditional mussel bed areas by Te Ūpokorehe representatives. The traditional bed areas were consistent with local knowledge shellfish distribution maps published by the Ōpotiki Pollution Advisory Council in the Ōpotiki News newspaper, 26th January 1965.

In 2016 it was found the two of the traditional mussel bed areas (bed 2 and 3) recorded no mussels as present. It was found that Bed 1 in the eastern side (E1) recorded mussels as present with the bed boundary covering a total area of seven thousand, three hundred and ninety-one square metres (7391 sq.m). No other mussels were observed as present in the eastern side of the harbour (Fig 4).

However a significant presence of *Paphies australis* or pipi was observed adjacent to the traditional bed 2 area (E2) in the eastern side of the harbour.

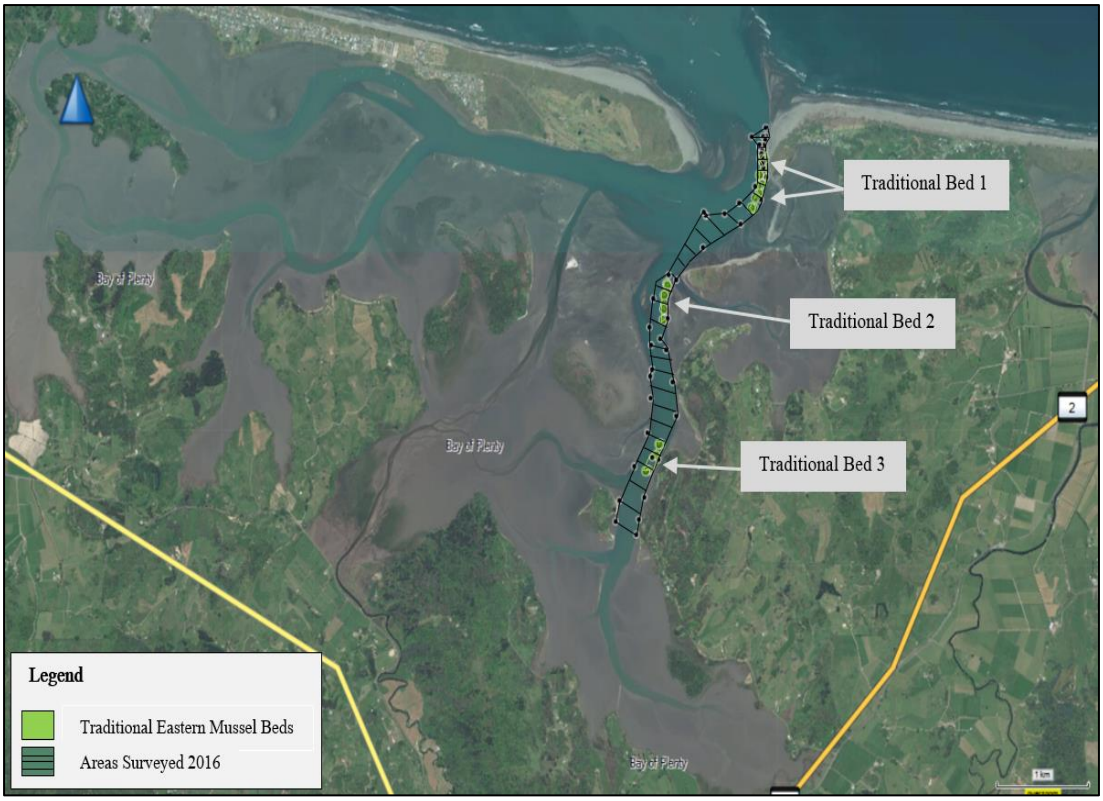

Figure 3. Eastern areas surveyed (black stripes) with traditional mussel bed areas (green) as identified by Te Ūpokorehe representatives (Imaging by Paul-Burke, 2016).

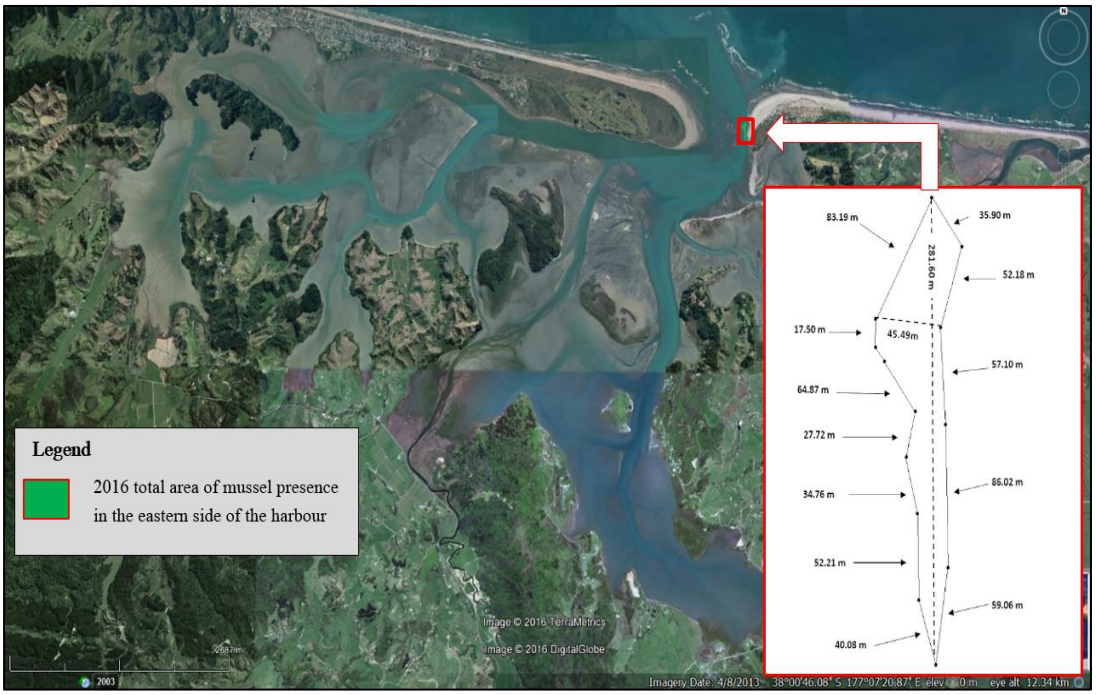

Figure 4. The 2016 Mussel Bed (red square) with measurements (metres) box (white) identifying distribution range of mussels in the eastern side of the harbour (Imaging by Paul-Burke, 2016).

12.1.3 *Mussel Distribution Ōhiwa Harbour*

In 2016 the combined total area of mussel bed boundaries in Ōhiwa Harbour was an estimated nineteen thousand, one hundred and ninety-four square metres (19,194 sq.m).

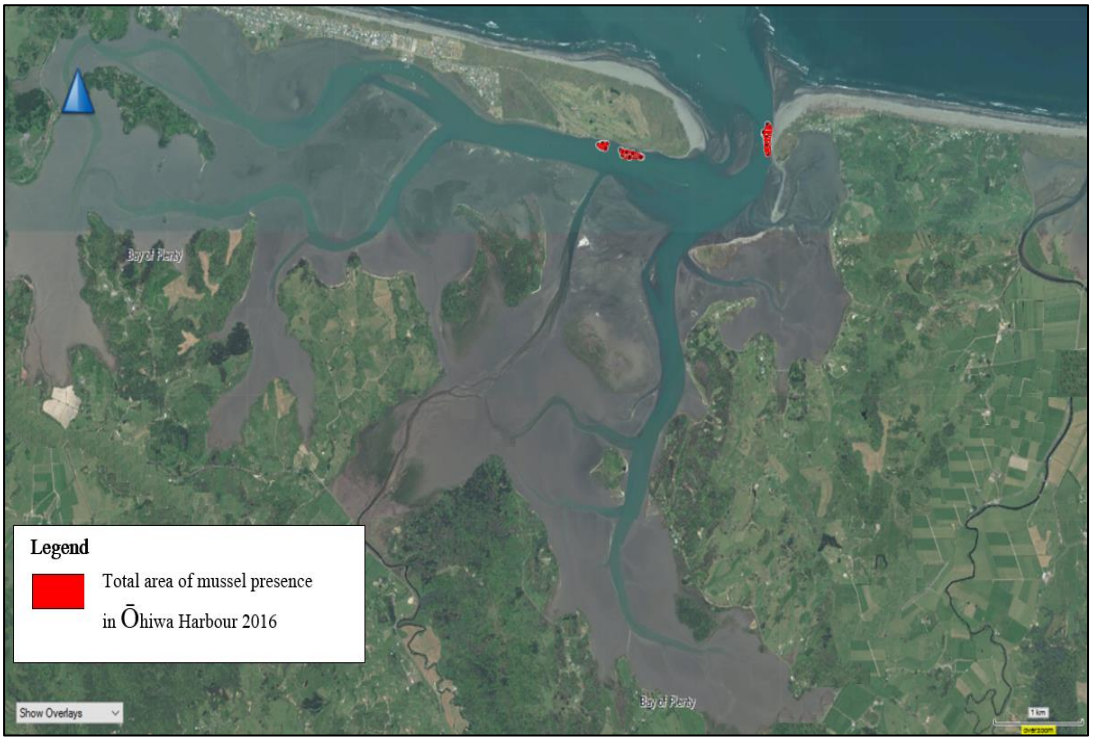

Figure 5. Distribution of mussel populations in Ōhiwa harbour (Imaging by Paul-Burke, 2016).

12.2 *Abundance in the Western side*

In 2007 there were an estimated one hundred and twelve (112) million mussels present in the original bed boundaries in the western side of the harbour. In 2008 there were an estimated fifty-seven (57) million, with an estimated sixteen (16) million mussels present in 2009. In 2013 there were an estimated two (2) million mussels present in the original bed boundaries. In 2016 an estimated four hundred and eighty-four thousand, eight hundred (484, 800) mussels were identified as present in the western side of the harbour (Fig 6).

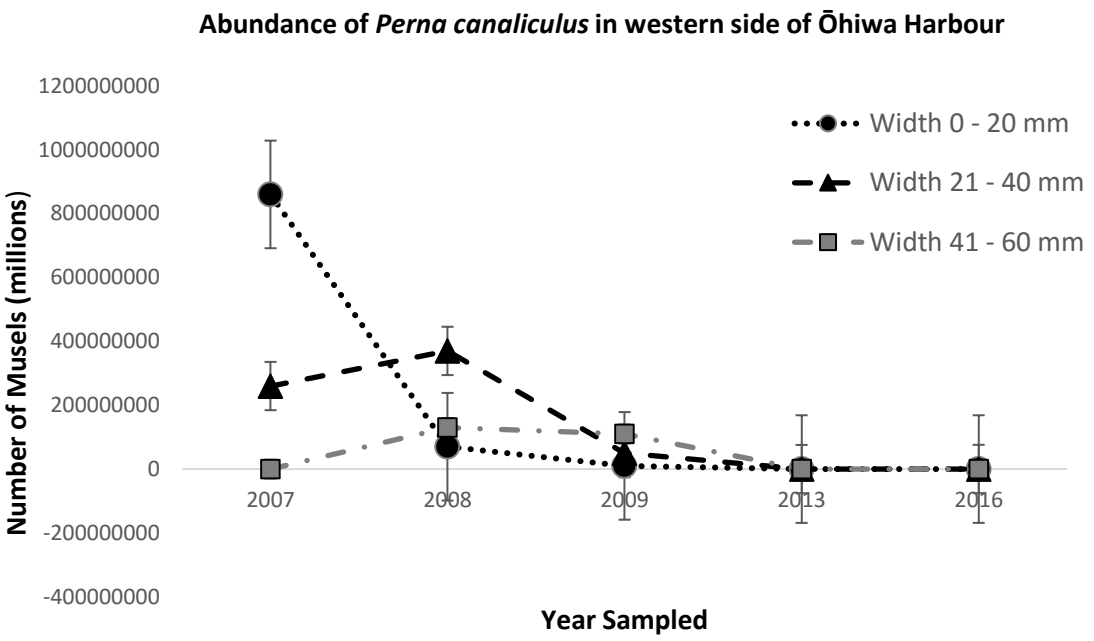

Figure 6. Abundance in total number (millions) of Mussels in the western side of Ōhiwa harbour. Error bars indicate the 95% confidence interval on the Total estimate.

Results of two independent samples T Tests using unequal variance were conducted with each yearly total tested against the next year's total. It was found in 2007 that the total number of mussels present was significantly different from 2008 ($p = 0.004$). The 2008 total number was significantly different from 2009 ($p = 0.004$). The 2009 total number of mussels was significantly different from 2013 ($p = 0.47$). The 2016 total number of mussels was significantly different from 2013 ($p = 0.00$).

In 2016, it was found that ninety-nine point six percent (99.6%) of the original mussel population in the western side of the harbour was no longer present.

12.2.1 *Abundance in the Eastern Side*

In the eastern side of the harbour there were an estimated fifty-nine thousand (59,000) mussels present. The combined total of the mussel population in the whole of Ōhiwa harbour (western and eastern sides) was estimated at five hundred and forty-three thousand, nine hundred and forty-two (543,942) mussels.

12.3 *Mussel Sizing*

In the western side of the harbour the majority of all mussels sampled in 2007 were identified in size class one (0-20mm) width, with an estimated eighty-six (86) million present. In 2008 the majority all mussels sampled were in size class two (21-40mm) width, with an estimated thirty-seven (37) million. In 2009 the majority of all mussels were sampled in size class three (41-60mm) width, with an estimated eleven million present.

In 2010, 2011 and 2012 no monitoring was conducted on the mussel populations. The sizing trends for the three consecutive unmonitored years are unknown. In 2013 the majority of all mussels sampled were identified in size class one, with an estimated one point four (1.4) million present in the western side of the harbour.

In 2016 the majority of all mussels in the harbour were identified in size class two, with an estimated three hundred and eighty-two thousand, two hundred and thirty (382,230) mussels present across all sites sampled (Table 1).

Table 1. Number in millions (m) and thousands (t) of Mussels in sampled size classes.

Year	**2007 Western Side**	**2008 Western Side**	**2009 Western Side**	**2013 Western Side**	**2016 Whole Harbour**
Width 0 – 20 mm	**86 m**	7 m	1 m	**1.4 m**	30,901 th
Width 21 – 40 mm	26 m	**37 m**	5 m	0.4 m	**382,230 th**
Width 41 – 60 mm	0	13 m	**11 m**	0.2 m	130,811 th
Total	**112 m**	**57 m**	**16 m**	**2.0 m**	**543, 942 th**

12.4 *Seastars Abundance and Sizing*

In 2009 there were an estimated one point two million (1.2) seastars in the identified mussel bed boundaries in the western side of the harbour. In 2013 there were an estimated ninety-nine thousand (99,000) seastars. In 2016 there were an estimated four thousand, seven hundred and twenty-one (4,721) seastars observed in mussel bed boundaries in the whole of Ōhiwa harbour. In 2016 a large population of seastars were observed in the pipi bed adjacent to the traditional mussel area 2 in the eastern side of the harbour with an estimated five seastars per every one square metre.

Results of two independent T Test with unequal variance were conducted with each yearly total tested against the next year's total. It was found that the 2009 total number of seastars was significantly different from 2013 ($p = 0.02$), and 2013 was significantly different from 2016 ($p = 0.00$). In 2016 ninety-nine point six percent (99.6%) of seastars are no longer present in comparison with the 2009 population.

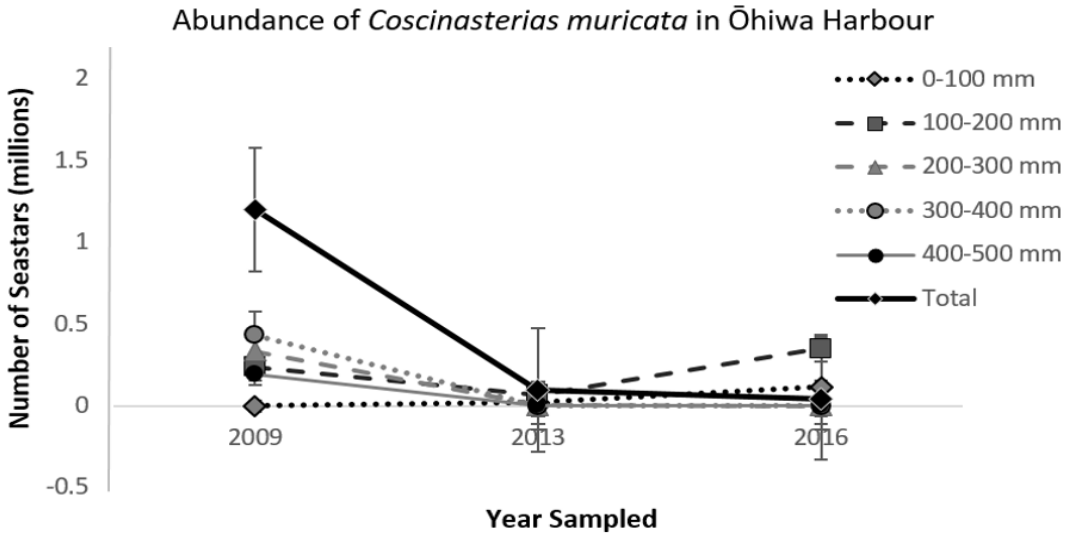

Figure 7. Abundance in total number (millions) of Seastars in Ōhiwa harbour. Error bars indicate the 95% confidence interval on the Total estimate.

In 2016 the majority of all seastars sampled were identified in size class two (100-200 mm) diameter. In 2009 the greatest number of seastars sampled were measured in size class 4 (300-400mm) and size class 2 (100-200mm) in 2013 (Fig 7).

13.0 DISCUSSION

13.1 Sub-tidal dive sampling surveys and distribution mapping was undertaken in the eastern and western sides of Ōhiwa harbour between the months of April-August 2016. A total of eighty (80) quadrat samples (0.25m² and 1m²) were conducted with a total of one hundred and thirty-four (134) dive marks recorded.

13.2 In 2016 there were an estimated five hundred and forty-three thousand and nine hundred and forty-two mussels (543,942) in the whole of Ōhiwa harbour. Previous results from the 2007 baseline sampling survey identified an estimated one hundred and twelve (112) million mussels with an estimated two (2) million mussels recorded in the western side of the harbour in 2013.

13.3 In 2016 an alarming ninety-nine point six percent (99.6%) of the original 2007 mussel population in the western side of the harbour were no longer present.

13.4 In 2007 the original mussel bed boundaries covered a total of one hundred and ninety-four thousand square metres (194,000 sq.m). In 2016 the total area of mussel bed boundaries in Ōhiwa Harbour was an estimated nineteen thousand, one hundred and ninety-four square metres (19, 194 sq.m).

13.5 In 2016 a significant ninety-four percent (94%) of the original 2007 bed boundaries in the western side of the harbour were no longer present.

13.6 In 2009 the seastar baseline surveys identified an estimated one point two million (1.2) seastars in the mussel bed boundaries in the western side of the harbour. In 2016 there were an estimated four thousand, seven hundred and twenty-one (4,721) seastars in the mussel bed boundaries in the whole of Ōhiwa harbour.

13.7 In 2016 ninety-nine point six percent (99.6%) of the original 2009 seastar population were no longer present.

13.8 In the eastern side of the harbour, three sites were identified as traditional mussel bed areas by Te Ūpokorehe representatives.

13.9 Baseline sampling surveys conducted in the eastern side of the harbour in 2016 identified only one of the three traditional mussel bed areas as present. A significant presence of pipi were observed adjacent to the traditional bed 2 area.

13.10 The only bed identified in the eastern side of the harbour covered an area of seven thousand, three hundred and ninety-one square metres (7,391 sq.m). No other mussels were observed in the eastern side of the harbour.

13.11 It was observed that the mussel population in the eastern side of the harbour was sparsely dispersed and presented in very small groups of an approximate two – ten individuals per grouping. There were an estimated fifty-nine thousand (59,000) mussels present.

13.12 It was observed that hard structures such as; boat moorings, underside of anchored yachts, navigation and ski lane buoys identified a significant presence of mussels in all areas of the harbour.

It was hypothesised that because the mussels attached to permanent structures suspended above the bottom substrate, seastars were unable to access and predate on them, allowing the mussels to flourish. However, further evidence is required.

13.13 In 2016 a small population presence of cockles, live horse mussels and one scallop were also observed in the eastern side of the harbour.

13.14 ***Silt in the Harbour***

In 2016, it was observed that the visibility within the harbour was significantly low. The lack of visibility severely restricted the ability for research divers to conduct distribution mapping and sampling counts in all areas of the harbour.

13.15 Between the months of April-August 2016, the average visibility range was recorded at a consistent 0-0.5 metres with limited light penetration through the water column.

13.16 In 2016, a significant dense layer of silt was observed covering the bottom substrate. In a harbour where eighty percent (80%) of the substrate is exposed at low tide, mixed with the strong tidal flows of up to seven knots and the light pumice soils of the surrounding catchment, Ōhiwa harbour and its mussel populations are directly exposed to sedimentation trapping. Whereby, silt is brought in by both the rivers and tides accumulating within the harbour[15].

13.17 After significant storm events, such as flooding and landslides, silt washing into the harbour from the surrounding catchment can suffocate and smoother shellfish beds. The rivers flowing into the harbour can carry large amounts of sediment and other materials, of which pollutants are included[16] consequently, the quality of water originating from the rivers into the harbour are of considerable importance to the health of the mussel bed populations.

13.18 This was particularly concerning in the western side of the harbour as mussels were observed as barely visible below a heavy layer of silt. In some instances researchers had to wipe away the silt to be able to correctly identify the mussels.

13.19 ***Pipi population***

In 2013 a significant population of pipi were observed adjacent to the mussel bed area in the western side of the harbour. In 2016, the pipi population were no longer present. However, significant layers of dead shell debris was observed.

13.20 In the eastern side of the harbour, a significant population of *Paphies australis* or pipi was present and located adjacent to the traditional mussel bed area (traditional area 2) as identified by representatives of Te Ūpokorehe hapū.

13.21 Previous studies of shellfish distribution and abundance undertaken by Pawley (2011) for the Ministry of Primary Industries (MPI) Fisheries in Ōhiwa harbour, were confined to commercial quota species of pipi and *Austrovenus stutchburyi* (cockles).

[15] Owen, 1992; EBOP, 2006, Paul-Burke, 2007.
[16] McLusky & Elliot, 2004;

Pawley's (2011) research did not include mussel populations or mussel distribution locations. Based on previous monitoring studies in 2005 and 2006, Pawley (2011) identified an increase in pipi numbers; however, the proportion of pipi numbers that were of harvestable size were noted as being significantly decreased.

13.21 In 2016 a large population of seastars were observed in the pipi bed adjacent to the traditional mussel area 2 in the eastern side of the harbour. Quadrat samples were taken and average of five seastars per every one square metre was recorded.

13.23 ***Seastars***

Seastars were observed to be disseminated within the newly identified 2016 mussel bed boundaries and did not present in a clustered state.

13.24 *Coscinasterias muricata* or eleven-armed seastars are the most common and largest seastar distributed throughout the temperate waters of Aotearoa New Zealand and southern Australia (Fig 8).

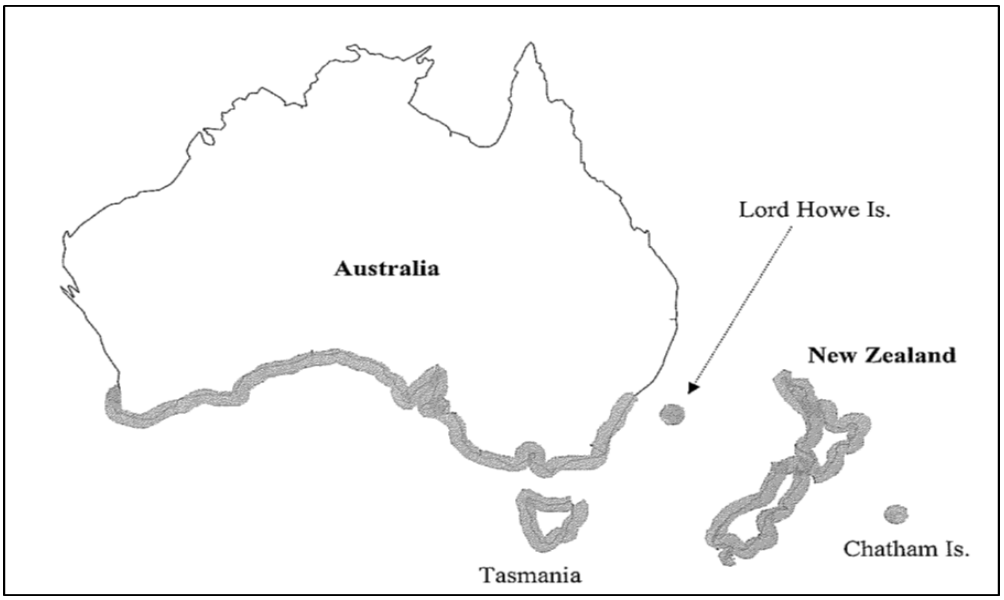

Figure 8. Map of Australasia, darker area show the distribution of seastars throughout southern Australia, Tasmania, Lord Howe Island, Chatham Island and coastal Aotearoa New Zealand (adapted from Channon, 2010).

13.25 Seastars are an important predator in sub-tidal (habitats that are consistently submerged or underwater) areas of sheltered bays and harbours, where they typically occur in low densities[17].

13.26 In a healthy system, sea-stars are a positive force, nibbling on mussels, keeping them in check from establishing a monoculture or singularly dominating or monopolising the bottom substrate and thereby reducing biodiversity.

13.27 However, a problem occurs when sea-star numbers run out of control. It is considered unsustainable when numbers rise to fifteen seastars per one hectare or 2.5 acres[18] One hectare is equivalent to ten thousand square metres (10,000 sq.m).

13.28 In 2016 a large population of seastars were observed in the pipi bed adjacent to the traditional mussel area 2 in the eastern side of the harbour with an estimated five (5) seastars recorded per every one square metre (1sq.m).

If the pipi bed in the eastern side of the harbour were to measure one hectare or ten thousand square metres (10,000 sq.m) the estimated seastar population would equate to fifty thousand (50,000) seastars per one hectre.

13.29 Management of seastar species is a global concern. On the Great Barrier Reef in Australian waters, population numbers for the Crown of Thorns Starfish (COTS) have reached epidemic proportions with catastrophe impact on coral reef communities.

13.30 Scientists have identified one cause of the population explosion of seastars as being attributed to the fertiliser run-off from farms, which flows in ever-increasing amounts into the rivers[19] and then into marine environments.

13.31 The run-off creates algal blooms, which provide a feast for seastar larvae if they occur during the spawning season.

[17] Barker, 2013; Lamare et al, 2009; Inglis & Gust, 2003
[18] Slezak, 206
[19] Slezak, 2016

According to Mercier & Hamel (2013) the main spawning event for *Coscinasterias muricata* coincides with the lowest sea-water temperatures[20] and under the right conditions, the seastar population explodes[21].

13.32 ***Mussel Management Action Plan***

The Ōhiwa Harbour Strategy contains an action 2.1, to investigate shellfish populations and advocate for sustainable shellfish management. This action has led to a proposal to build on investigations already carried out, into the state of the mussel beds in Ōhiwa harbour.

13.33 Previous surveys of the western mussel beds found that mussels were in decline and were being heavily predated by sea stars. A mussel management action plan (MMAP) was written by Paul-Burke (2014) and has been adopted by the Ōhiwa Harbour Strategy Coordination Group (OHSCG).

13.34 Phase one the MMAP (Fig 9) proposed a monitoring regime in the western side of the harbour and at the same time establish new baseline information in the eastern side of the harbour. This report is the culmination of phase one.

13.35 Phase two of the MMAP sought to generate information with literature reviews of mussel bed restoration and management of seastar populations. This was achieved by Tetai (2016).

13.36 The second stage of phase two in the MMAP was to develop technical designs for the restoration of mussel populations and best practice seastar management in Ōhiwa harbour taking into account the findings from the literature review written by Tetai (2016).

[20] Mercier & Hamel, 2013, p.44
[21] Slezak, 2016

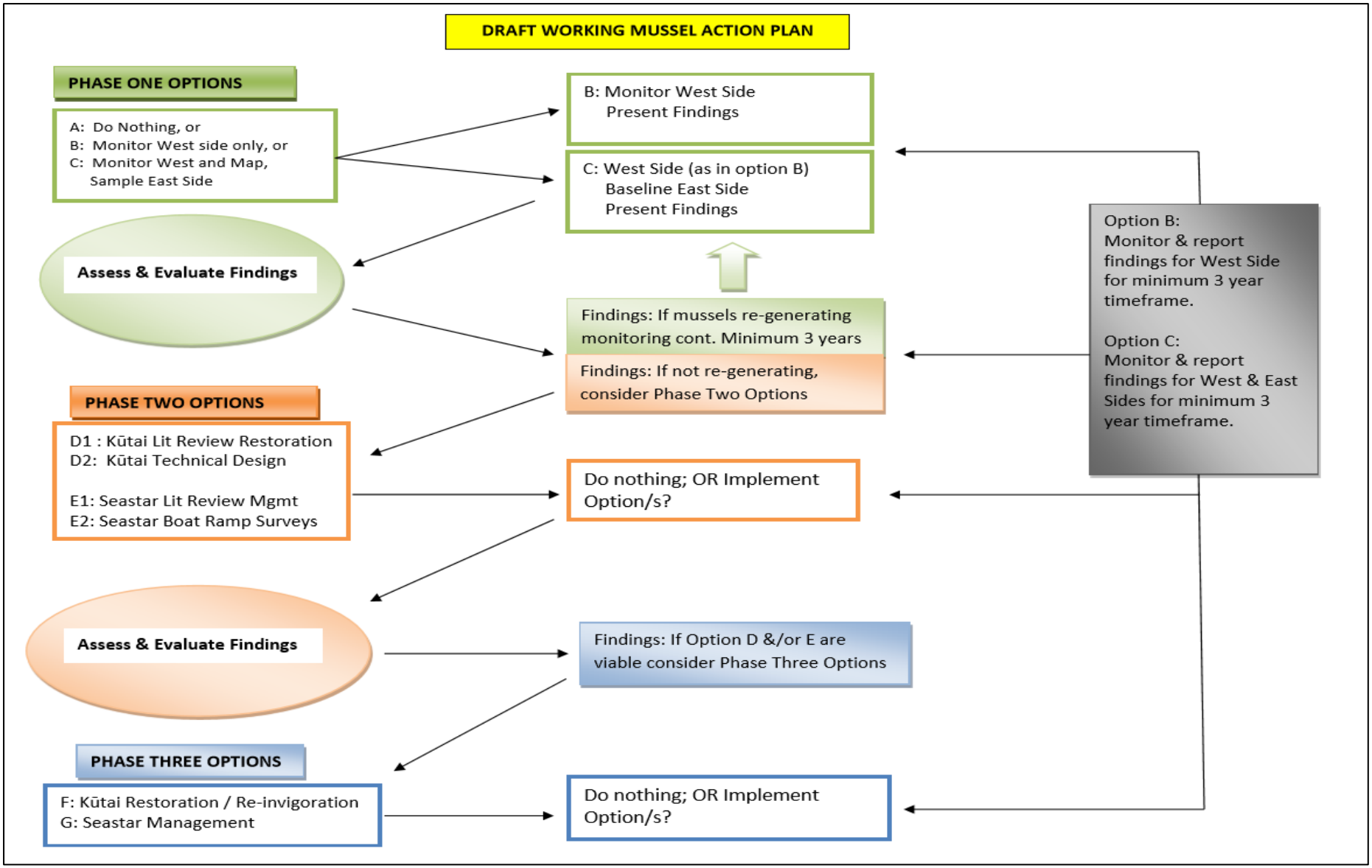

Figure 9. Mussel management action plan (MMAP) for Ōhiwa harbour. Kūtai = green lipped mussels (Paul-Burke, 2014).

14.0 RECOMMENDATIONS

Based on the findings in this report and consistent with Phases one and two of the MMAP, it is recommended that:

1. Sub-tidal monitoring and reporting on the state of mussel populations in Ōhiwa harbour be continued for a minimum total of three years.

2. Technical designs for the restoration and re-invigoration of mussel populations inclusive of mātauranga Māori with western science be developed.

3. Best practice seastar management plan for Ōhiwa harbour be initiated.

4. Opportunities for capability building of hapū/iwi kaitiaki be included into future field based research and/or monitoring for mussels and other shellfish programs in Ōhiwa harbour.

5. Collate and regularly report the findings of catchment wide information pertaining to sedimentation and silt deposits into the harbour.

6. Consideration be given to the establishment of a harbour wide shellfish monitoring program.

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